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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

WESTINGHOUSE AIR BRAKE
NEW YORK AIR BRAKE
CAR LIGHTING
CAR HEATING
ELECTRIC HEADLIGHT

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SCRANTON:
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PREFACE.

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one or to rise to a higher level in the one he now pursues. Furthermore, they wish to obtain a good working knowledge of the subjects treated, in the shortest time and in the most direct manner possible.

In meeting these requirements we have produced a set of books that in many respects, and particularly in the general

plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections, and sections or outline, partially shaded, or full-shaded perspectives, have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequalled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks,

together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one to select the proper formula, method, or process and in teaching him how and when it should be used.

This volume is devoted to the Westinghouse and New York air brake systems, car lighting, car heating, and the electric headlight. In it, the entire field of the air brake has been thoroughly covered, and great pains have been taken to treat the subject from the standpoint of the men who handle the brakes. Everything that will affect the operation of either air brake system has been carefully considered, and the defects and their remedies are treated in such a manner as to cover every case likely to arise. As both air brake systems are treated independently, there is necessary a certain amount of repetition in the presentation of the two subjects, which was impossible to avoid. Car lighting and car heating are treated in a similar manner and cover the entire field of lighting and heating from the trainmen's standpoint. This work should prove invaluable to all persons interested, either directly, or indirectly, in the operation, care, or maintenance of the air-brake, car-lighting or car-heating systems.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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RED.	*Main-Reservoir Pressure.*
PINK.	*Brake-Cylinder Pressure.*
GREEN.	*Auxiliary-Reservoir Pressure.*
LIGHT GREEN.	*Supplementary Reservoir Pressure.* (*Brake Valve Reservoir 155.*)
ORANGE.	*Atmospheric Pressure.*
YELLOW.	*Train-Pipe Pressure.*
BLUE.	*Live Steam.*
LIGHT BLUE.	*Exhaust Steam.*
BROWN.	*Air Under a Pressure of About Three Atmospheres.*

KEY TO THE COLOR PLATES.

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THE AIR BRAKE.

(PART 1.)

HISTORICAL.

1. The forms of brake in general use before the adoption of the air brake were the hand and the spring brake; most trains, however, were controlled by hand power.

Both of these brakes were ineffective, even for the slower speed of trains in those days, and a field of invention was open for the production of a brake that would permit of a higher safe speed for trains. Mr. George Westinghouse, Jr., brought out the first form of air brake, called the "Straight-Air" Brake, in 1869.

THE STRAIGHT-AIR BRAKE.

2. General Equipment.—The engine equipment that was employed in connection with this kind of brake consisted of a pump, a main reservoir, an engineer's valve, a gauge, and a train line. A pipe connection between the pump and main reservoir allowed the pump to compress air directly into this reservoir, and the air thus compressed was stored in the reservoir for braking purposes. A pipe led from the main reservoir to the engineer's valve, which at that time was a **three-way cock.** This valve had three positions, namely, *lap*, *service*, and *release.* The improved three-way cocks had a *running position* and an *excess-pressure valve.*

With the valve *on lap*, all ports were closed, and there could be no passage of air through the valve; in *service position*, a port

was opened between the main reservoir and the train line; and in *release position*, a port connection was established between the train line and the atmosphere.

On each car, and on the tender, were placed a brake cylinder and a train pipe, a hose being provided at each end of the train pipe to enable the train line to be coupled up throughout the train. The train pipe on the car was directly connected with the brake cylinder, so that, if any pressure was in the train pipe, the same pressure was in the brake cylinder.

3. Operation.—While the brakes were off, and before they could be operated, the pump compressed the desired pressure into the main reservoir. If the engineer wished to apply the brakes, he placed the three-way cock in *service position.* This position of the valve allowed main-reservoir air to pass through the three-way cock into the train line, and thence into the brake cylinders, since the brake cylinders were directly connected with the train line. When the desired pressure had been admitted to the train line and brake cylinders, the three-way cock was placed *on lap*, in which position all ports were blanked. The pump would continue compressing air into the main reservoir, to be put into the train pipe when the valve was again placed in service position.

To release the brakes, the engineer placed the valve in *release position*, which allowed air coming from the train line and brake cylinders to pass to the atmosphere through the three-way cock.

4. Defects.—With this form of brake, the brakes on the entire train were rendered useless if a hose burst or if the train broke in two, as then the air admitted into the train pipe to set the brakes would pass to the atmosphere through the burst hose instead of into the brake cylinder. Aside from this, there were several other serious defects in this brake. On a long train, the main reservoir, when connected with the train pipe and brake cylinders through the three-way cock, would equalize at a low and comparatively ineffective braking pressure, as a consequence of which, considerable time was required to stop a train. Again, air entering at the head of the train had a tendency to apply

the brakes at the head end first, and, when a sudden application of the brakes was made, the slack, running ahead from the rear, would often do serious damage to the cars and their contents. The effect of friction on the flow of air through the train pipe also hindered the free passage of air through the train pipe, causing the brake to be slow in its action, both in application and release.

THE AUTOMATIC BRAKE.

5. Automatic Air Brake.—The many defects of the straight-air brake led to further study, invention, and experiment, the result being the introduction of the *automatic air brake* by Westinghouse in 1873.

The adoption of the automatic brake necessitated the addition of an auxiliary reservoir and plain triple valve under each car and tender, but did not, for the time being, affect the engine equipment—the brake valve, reservoir, etc.

With the automatic brake, the necessary braking power, regardless of the length of the train, was stored in the auxiliary reservoir under each car, for use on that particular car; and, if a hose burst or the train parted, the triple valves would automatically apply the brakes on the whole train—something that could not result on a train equipped with the straight-air brake. Thus, a safer and quicker brake was obtained. Even this one, however, was found to be too slow in its action in cases of emergency, the brakes not setting with sufficient rapidity to avoid damage when the slack in the train ran ahead. When a quick reduction of train-pipe pressure was made, the head brakes would be set in full before the reduction reached the rear of the train, this retardation being due to the friction of the air in the long train pipe.

The trouble thus experienced with the plain triple led to the invention of the *quick-action triple valve* that was brought out by Westinghouse in 1887. This valve could be substituted for the old-style valve on trains already equipped, no other changes in the system being necessary, except the use of a larger train pipe.

6. High-Speed Brake.—The straight-air brake is now practically a thing of the past; the plain automatic is used only on engines, tenders, and a few old-style car equipments put on years ago; while the **quick-action automatic** is in general use on both freight and passenger cars throughout the country.

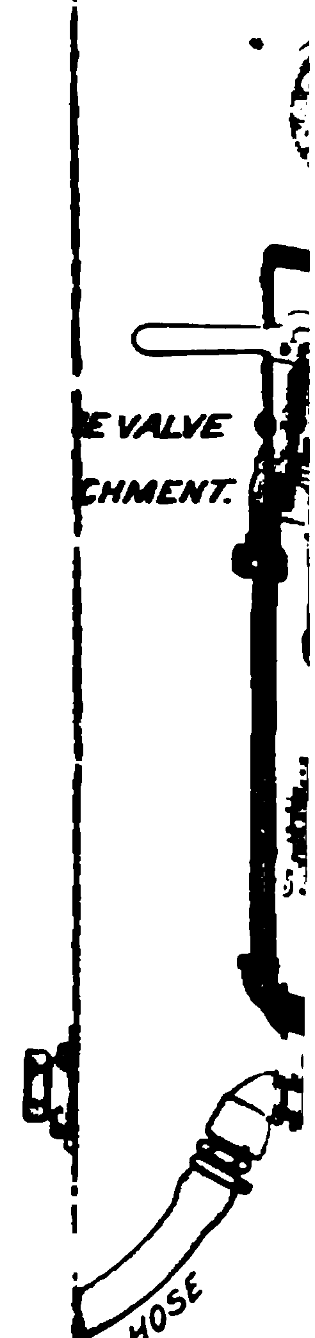
The demand for trains having a schedule speed of more than 50 miles an hour has made necessary a brake even more powerful than the quick-action automatic. Such a one is the **high-speed brake,** as now used on fast-timed trains like the "Empire State," the "Black Diamond," the "Congressional Limited," etc.

WESTINGHOUSE AUTOMATIC AIR BRAKE.

GENERAL ARRANGEMENT OF BRAKE.

7. Air Pump.—The essential parts of the **Westinghouse automatic air brake,** and their arrangement on the engine, tender, and passenger car, are shown in Fig. 1. The *air pump,* generally placed above the right running board in front of the cab, consists of a steam cylinder *1* and an air cylinder *2*. The two pistons working in these cylinders (one in each) are attached to the same piston rod, as seen in the figure. Therefore, the air piston moves up and down exactly as the steam piston does, and thus compresses the air to be used in the brake system. When the compressed air leaves the pump, it goes to the main reservoir and to the engineer's brake valve; thence, in certain positions of this valve, it passes through the same into the train pipe, and thence through the triple valves into the auxiliary reservoirs. A pressure of 90 pounds is stored in the main reservoir on the engine for the purpose of releasing brakes and recharging the auxiliaries and train pipe.

8. Pump Governor.—The *pump governor 3* is placed in the steam pipe leading to the pump, being located between


E VALVE
CHMENT.
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it and the lubricator. It acts as an automatic throttle valve that stops the pump when the desired air pressure is obtained in the main reservoir or train pipe (to whichever it may be connected), and starts it again when, for any reason, this pressure falls below the desired amount.

9. Main Reservoir.—This reservoir, which is usually placed under the engine, just back of the cylinders, is a store chamber in which a large supply of compressed air is maintained. This supply of air is used to charge the train pipe and auxiliaries, and to release brakes, if set, by charging the train pipe to a higher pressure than that in the auxiliaries; also, to feed any train-pipe leaks while the brakes are released. The usual main-reservoir pressure is 90 pounds, but this is exceeded (1) in mountain districts, (2) when handling very long trains, (3) when the train is equipped with the high-speed brake, or (4) when the Westinghouse special attachment for controlling heavy trains on long down-grades is used.

10. Engineer's Brake Valve.—This valve is located in the cab of the engine, in a position convenient to the engineer. Its function is to regulate the flow of air from the main reservoir to the train pipe, and through chamber D in the brake valve to the small *equalizing reservoir* under the right running board, sometimes called the *brake-valve reservoir*, or "little drum"; from the train pipe through the engineer's valve to the atmosphere; and from chamber D, the equalizing reservoir, and train pipe to the atmosphere; also, if desired, it prevents any flow of air whatsoever. The equalizing reservoir is connected to chamber D of the brake valve, with the object of increasing the volume of that chamber. Air passes through chamber D when going either into or out of the brake-valve reservoir.

11. Air Gauge.—The *air gauge 4* is placed in the cab in such a position that it may be easily seen and read by the engineer. It generally is a *duplex* pattern, and really consists of two gauges. It has two hands or pointers—one colored red and the other black. The red hand indicates the main-reservoir pressure; the black one shows the pressure in the chamber D

(of brake valve) and the equalizing reservoir, this pressure being generally the same as that in the train pipe. Although the gauge pipe leading to the black gauge hand is connected with the equalizing reservoir, the black hand, for reasons that will be explained in the study of the engineer's valve, is generally spoken of as indicating train-line pressure.

12. Cut-Out Cock.—A *cut-out cock 5* is placed in the train pipe just below the brake valve. This allows the brake valve to be "cut out" from the train line for the purpose of testing, or when this particular engine is the "following" one of a "double-header," and the brakes are to be controlled by the leading engineer.

13. Train Pipe and Attachments.—Mention has already been made of the **train pipe**. It is the pipe that leads from the brake valve back through the train, and is connected to the triple valves by means of **branch pipes.** It is through the train pipe that air, after leaving the brake valve, is conducted to the triple valves, through which valves it passes into the auxiliary reservoirs. The pressure usually carried in the train pipe is 70 pounds, except in mountainous districts and on trains equipped with the high-speed brake already referred to. The sections of train pipe under adjacent cars are connected by means of flexible rubber *hose* and suitable *couplings.*

Angle cocks, for the purpose of closing the train pipe, are placed at each end of a car, in case it should be necessary to switch the car, or if for any reason it should be necessary to disconnect the hose, as well as to close the rear end of the train pipe. Angle cocks, in all modern equipments, are open when the handle stands parallel with the train pipe, as shown in Fig. 1, and closed when at right angles to it.

The handle of the cut-out cock *6*, Fig. 1, stands at right angles to the branch pipe when the cock is open, and parallel with it when closed. In very old equipments, however, the older form of cut-out cock is used, their handles standing crosswise of the pipe when closed. If there is any doubt as to whether a cock is open or closed, glance at the crease in the top of the plug valve. This crease should be parallel with the pipe when the

cock is open. If the brake on any car is defective, it may be cut out by closing the cut-out cock *6*, without affecting the operation of the brakes ahead of, or behind, that car.

14. Auxiliary Reservoir.—An *auxiliary reservoir* should be placed on each engine, tender, and car; the old custom of using one auxiliary for both engine and tender is now considered very poor practice, and is seldom met with. The function of the auxiliary reservoir is to receive and store air for use in applying the brake on the car on which it is placed. Auxiliary pressure, when fully charged, is equal to train-pipe pressure.

15. Brake Cylinder.—A *brake cylinder*, in which a piston operates, is placed under each car of the train. The brake levers are connected to the crosshead *7*, Fig. 1, in such a way that, when air pressure is admitted to the brake cylinder and forces the piston out, the brake shoes are forced up to the wheels.

16. Triple Valve.—This valve is connected at the junction of the train pipe, auxiliary reservoir, and brake cylinder. It has three duties to perform: (1) to charge the auxiliary by connecting it with the train pipe; (2) to apply the brake by connecting the auxiliary with the brake cylinder; and (3) to release the brake by connecting the brake cylinder with the atmosphere.

17. Conductor's Valve.—This valve is placed only on cars in passenger, mail, baggage, express service, and on cabooses. It is generally located at the end of the car, and is connected with the train pipe by a branch pipe. This valve is intended for the trainmen's use, so that they may have the power to stop the train in case of an emergency of which the engineer is ignorant. A cord running the full length of the car is connected to this valve; when this cord is pulled, it opens the valve and allows air to escape from the train pipe, which causes the brakes to apply.

18. Drain Cups.—These cups are placed on all engines, tenders, and cars. Each *drain cup* contains a screen to keep dirt and other foreign matter from reaching the triple. The

drain cup on the tender is made larger, as it collects considerable moisture, which should be drawn off through the *drain cock* after each trip.

MAIN RESERVOIR.

19. The **main reservoir** (Fig. 1) is an air-tight cylinder having a pipe connection with the pump and also one with the engineer's brake valve.

SIZE.

20. Main reservoirs vary in size according to the kind of service—freight or passenger—in which the engine is employed. The following table gives the standard sizes:

STANDARD SIZES OF MAIN RESERVOIR.

Outside Dimensions.		Capacity. Cubic Inches.
Diameter. Inches.	Length. Inches.	
26½	34	15,800
24½	41	17,400
26½	41	20,700
16	120	22,000
18½	102	25,200
20½	114	35,000
26½	96	49,400

In the best practice, a main reservoir of not less than 16,000 cubic inches capacity for passenger, and 20,000 for freight, service is used.

A larger main reservoir is necessary on freight than on passenger engines, (1) because of the greater number of air cars handled in a train in freight service; (2) because there is a longer train pipe and more auxiliaries to recharge after the brakes are released; and (3) because the greater the volume of air in the main reservoir, the higher the pressure at which the

main reservoir and train pipe will equalize, and the easier, therefore, it will be to release brakes.

It is often found that when a pump is heating, the trouble will disappear entirely if the capacity of the main reservoir is increased. If the train is long and the main reservoir small, a high pressure must be carried in the latter in order that it may equalize with the train pipe at a sufficiently high pressure to promptly release the brakes and recharge the auxiliaries. When the main reservoir is large, a much lower reservoir pressure can be carried, and the pump can also store a greater quantity of air while the brakes are applied. When, therefore, the main reservoir is small, the pump must work both faster (or longer) and against a higher pressure, and either of these tends to cause overheating.

LOCATION.

21. The main reservoir is usually located between the frames, back of the cylinder saddle. This is the most approved location, although it is sometimes found advisable to sacrifice the location in order to use a main reservoir of the desired capacity. It should, if possible, be located *lower than the air pump* in the brake system on the engine, in order that all dirt, oil, and moisture will settle there. Then it may, and should be, drained after each trip, a drain cock being provided in the bottom of the reservoir for this purpose. When water is allowed to accumulate in the main reservoir, it not only reduces the space available for storing air, but if the pipes of the brake system are not properly arranged on the engine, it will work back into the brake system, carrying dirt and oil with it, which gums up the brake valve and triples and prevents the brakes from working properly. There is also danger, in winter, of the water freezing and stopping up the pipes. The water that gets into the brake system is mostly drawn into the air end of the pump with the air. This is especially true on damp and rainy days. The main reservoir is sometimes located between the frames under the deck, sometimes on top and at the back of the tender, and frequently under the cab running board. It is also occasionally seen on top of the boiler, back of the bell.

When the main reservoir is located on the tender, it is necessary to run a line of pipe from the pump back to the tender, and a return pipe from the main reservoir to the engineer's valve. This proves rather expensive, the more especially as dirt and moisture settle in the hose connections between engine and tender and soon destroy them.

The objection to placing the main reservoir between the frames under the deck is that the reservoir is in the way when working at the wedges, boxes, and dampers.

It is not unusual to use two small main reservoirs, in which case the air should go from the pump to one of them, thence passing into the second one, and from there to the brake valve.

DUPLEX AIR GAUGE.

22. **A duplex air gauge,** which indicates both train-line and main-reservoir pressures, is located in the engine cab, in a position convenient for the engineer to see. This gauge, shown in views (*a*) and (*b*), Fig. 2, consists really of two gauges combined in one, the same dial serving for both hands. The right-hand gauge, which, as seen, connects with *T*, operates the black hand. This hand is said to represent train-pipe pressure, although *T* really has a pipe connection to chamber *D* and the equalizing reservoir at *W*, Figs. 14 and 16; but the study of the engineer's valve will develop the fact that equalizing-reservoir and train-pipe pressures are usually equal. The other connection *M*, a part of the left-hand gauge, is piped to *R*, Figs. 14 and 16, so that this hand, colored red, indicates main-reservoir pressure.

23. **Principle of Working.**—An inside view of the air gauge is shown at (*b*), in which *A* and *B* are two bent tubes of elliptical shape, as shown at (*d*). The tube *B* is connected to the fitting *T*, and the tube *A* to the fitting *M*. The bottom ends of the tubes are held fast, the top ends are closed and free.

The **action of the gauge** may be thus explained: If a tube of elliptical section is bent as shown in view (*b*), and then

(a)

(b)

FIG. 2.

subjected to an internal pressure (of either a gas or a liquid), the force exerted will tend to straighten the tube. This is due to the fact that the force exerted within the tube tends to make it assume the circular form shown dotted in view (*c*). In assuming the circular form, the concave side *a* of the bent tube tends to lengthen, while the convex side *b* tends to shorten. These combined efforts tend to straighten the tube out, and therefore impart a movement to its free end.

Tube *A* is connected to one end of the lever *kj* by means of the link *c*. This lever is pivoted at *e*, and the end *j* forms a toothed sector that meshes with a pinion on the spindle *i*. The spindle *i* carries the red hand, or pointer, of the gauge, and rotates within a hollow spindle *l*, which carries the black hand. Tube *B* is connected by link *b* to the lever *fg* at a point below the fulcrum, or pivot, so that the black hand will be turned in the same direction as the red one. The lower end of the lever *fg* takes the form of a toothed sector that meshes with a pinion on the hollow spindle *l* and operates the black hand.

24. Operation of Gauge.—Since the main reservoir connects with *M*, air under pressure enters tube *A* and tends to straighten it out. This causes the free end of *A* to move to the left, drawing the link *c* with it, thus moving the toothed sector *j* to the right. As this sector engages with the spindle *i*, the latter is made to move clockwise—that is, to have a motion in the same direction as the hands of a clock. The red hand is also given a similar motion.

Train-pipe pressure acts within the tube *B* to straighten it, and the free end is moved to the right. As the bar *b* is connected *below* the fulcrum of the lever *fg*, the movement of the free end of *B* will cause the toothed sector *g* to move to the right and turn the black hand clockwise also. The greater the pressure within the tubes, the greater will be the tendency for them to straighten out, and the higher will be the pressure registered by the gauge; *d* and *h* are small coiled springs to take up the play or backlash in the teeth of the sector and pinion.

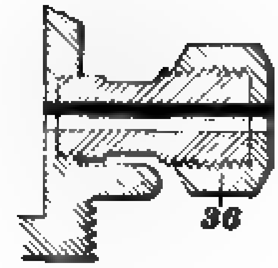

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FIG 3.

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Fig. 3.

Fig. 4.

PUMP GOVERNORS.

DESCRIPTION.

25. The operation of the old style of pump governor, Fig. 4, is so nearly similar to that of the improved type, Fig. 3, that a description of the latter will suffice for both. The characteristics of the two governors will be considered later on.

The steam-supply pipe to the air pump leads from the top of the dome to a throttle, usually conveniently situated in the cab. From the throttle, the pipe leads to the steam connection *X*, Figs. 3 and 4, of the **pump governor,** the other connection *Y* of which is piped to the pump, as shown in Fig. 1. In order to reach the pump, all steam must pass through the pump governor, whose function is to shut off steam from the pump when the desired air pressure is obtained, and to admit it again when the air pressure falls below the amount desired.

When used in connection with a D-8 engineer's brake valve having an excess-pressure valve, the governor is connected to, and operated by, train-pipe pressure, the pipe connection being made at *z*, Figs. 3 and 4. When used with the F-6 brake valve having the feed-valve attachment, the governor is operated by main-reservoir pressure, the pipe connection to the governor being made at *z*, as before.

26. Referring to Fig. 3, it will be seen that chamber *a* is in direct communication with the pipe connection *z* that leads to the main-reservoir pressure when used with the F-6 brake valve. *42* is a brass diaphragm that, in moving, operates the pin valve *b*. *41* is a regulating spring that tends to drive the diaphragm *42* down with a force just a trifle less than the pressure in *a* at which the governor is intended to operate. *28* is the governor piston, to which the steam valve *26* is attached by means of its stem and the locknuts. *31* is the piston spring, whose duty is to hold the steam valve *26* from its seat when there is no air pressure above piston *28*; it does this by forcing the piston upwards, carrying the valve *26* along. *29* is a packing ring, made a sufficiently good fit to prevent any serious

leakage of air from chamber *e* past the piston. In the old style of governor, Fig. 4, the packing ring *24* was made loose so that air would leak past piston *5*. This point, however, will be taken up again when describing the operation of the governor.

The dotted circles seen below governor piston *28* show where the drip-pipe connection *36* is made. The position of the drip pipe on the old governor is also shown by dotted circles. The object of a drip pipe is to permit the escape to the atmosphere of any air that leaks past the ring *29* or of any steam that leaks up by the stem of the steam valve *26*, instead of allowing it to accumulate under piston *28*.

A small port *f* is drilled in the new governor steam valve *26*. Its purpose is to maintain a circulation of steam in the supply pipe, and to keep the pump working slowly, thereby keeping the latter warmed up and preventing, to a great extent, the condensation of steam when the pump is started. If the pump were inactive for some time after full main-reservoir pressure had been attained, steam would condense, and the condensation would be thrown out of the stack, upon the engine jacket, when the pump next started to work.

In the following explanation, it will be assumed that the governor is to be used with the F-6 brake valve, and, therefore, is operated by main-reservoir pressure.

OPERATION OF GOVERNOR.

27. The regulating spring *41* is, as a general practice, adjusted so that it will just withstand a main-reservoir pressure of 90 pounds pushing upwards on the diaphragm *42* (see Fig. 3). When the pump is in operation, the pressure in the main reservoir, and, consequently, in chamber *a* of the governor, increases until a pressure of 90 pounds is reached. When the pressure in chamber *a* just slightly exceeds the pressure exerted by the regulating spring *41*, the diaphragm *42* is raised, carrying the pin valve *b* with it. The air in chamber *a* passes by the unseated pin valve *b*, down through port *d*, and into chamber *e* on top of the piston *28*, forcing it down and thus seating the steam valve *26*. As long as main-reservoir pressure

remains at 90 pounds, the diaphragm *42* will hold the pin valve *b* from its seat, and the pressure in chamber *e* will hold the steam valve *26* to its seat. If the main-reservoir pressure falls below 90 pounds, the thrust of the spring tending to force the diaphragm *42* down will overcome that of the air in chamber *a* tending to force it up. Consequently, the diaphragm will move downwards and thus seat the pin valve *b*.

This shuts off the air supply from chamber *e*, and the air confined therein by the pin valve closing will escape to the atmosphere through the relief port *c*. The pressure now being removed from above the piston *28*, the spring *31*, aided by the steam under valve *26*, forces the piston upwards, unseating valve *26*, and allowing steam to pass through the governor to the pump. The piston *28* is made sufficiently larger than the steam valve *26* to enable a moderate air pressure to easily hold valve *26* to its seat against the combined upward force of the steam pressure under the valve and the push of spring *31*.

28. The operation of the governor is the same, whether used with the F-6 or with the D-8 brake valve. In the former case, however, the governor is operated by main-reservoir pressure; whereas, in the latter case, it is operated by train-pipe pressure. In this case, the spring *41* must be adjusted to just withstand an upward pressure on the diaphragm *42* equal to train-pipe pressure, usually 70 pounds.

In the *old-style* governor, as soon as the pin valve *17* closes, the air entrapped above piston *5* leaks by the packing ring *24* (which is purposely made a loose fit), and escapes through the waste-pipe stud *10* located in the casting, as shown by the dotted circles. The rapidity with which the air above piston *5* will escape and permit the governor to operate, depends on the condition of the governor and fit of packing ring *24*. In some cases, the leakage is so slow that fully half a minute elapses after the pin valve is closed before the governor starts the pump.

The *improved* governor is provided with a relief port *c*, Fig. 3, the object of which is to enable the governor to start the pump promptly when the pressure in chamber *a* allows the pin valve *b* to close. The relief port communicates with chamber *e*,

and is of such a size as will, in two seconds after the pin valve closes, release sufficient air from above piston *28* to enable the governor to start the pump. This port permits a constant leakage of air from chamber *a* as long as the pin valve is open, which is usually sufficient to keep the pump running slowly.

The small port *f* drilled through the steam valve *26* in the improved governor is provided, as has already been stated, to allow sufficient steam to pass to the pump when the steam valve is closed, to make the pump take a stroke or two occasionally, thus keeping it warmed up. In the old governor, the pump ceases to work after full pressure is attained, except so far as may be required to supply any leaks in the brake system that would otherwise reduce the train-pipe pressure below 70 pounds.

THE 8-INCH AIR PUMP.

29. Fig. 5 shows a cross-sectional view of the Westinghouse **8-inch air pump** as used at the present time. In the illustration, *3* is the **steam cylinder,** and *2* its head; *4* is the **centerpiece** that forms the bottom head of the steam cylinder and also the top head of the air cylinder, *6* being the lower head of the latter cylinder.

We shall first describe the steam cylinder and head, and explain its mode of working—then deal with the air cylinder.

THE STEAM CYLINDER.

30. Description.—On referring to Fig. 5, two pistons *7* and *7′* of unequal diameters will be observed, connected together by the stem *7″*, the whole forming what is known as the **main steam valve;** *8* and *9* are the upper and lower main-valve packing rings, respectively; *10* is the steam piston and *10′* the piston rod, to the lower end of which is connected the air piston *11*. The steam end of the piston rod *10′* is made hollow to receive the reversing rod *17*, which works up and down inside it. *12* and *13* are piston packing-rings; *23* is the reversing piston, which is $\frac{1}{8}$ inch larger in diameter than piston *7*; *24* is

the reversing-piston packing ring; and *16* is the reversing slide valve, which is brought into play to reverse the movement of the steam piston *10*.

31. The **main valve,** which is also called a **differential valve,** controls the admission to, and the exhaust of steam from, cylinder *3*. It works inside the bushings *25* and *26*, contained inside chamber *m*, one at each end. Each bushing has two rows of ports (circular holes) *s*, *e*, and *s′*, *e′*, respectively. The ports *s* and *s′* are the admission ports, and *e* and *e′* are the exhaust ports. The stop-pin *50* prevents the main valve from dropping below the bushings *25* and *26* far enough for the packing rings *8* and *9* to expand and so prevent the valve from taking an upward stroke. The steam-supply pipe from the pump governor is connected to the pump at *X*, and, all the time the pump is operating, chamber *m* is full of steam, and acts as a steam chest for the steam cylinder *3*. Port *h* in chamber *m* leads to chamber *l* in the reversing-valve bushing *19*, which serves as a steam chest to furnish steam to the space above the reversing piston in chamber *d*. The **reversing valve** *16*, which works inside the reversing-valve bushing *19*, moves up and down with the reversing rod *17*, any movement of the rod causing a corresponding one in the reversing valve. The **reversing piston** *23* works in the bushing *22*, and has a stem that passes through the bushing and bears on the main valve stem *7″*.

32. The upper end of the reversing rod works freely inside the cap nut *20*. One end of port *x* opens into the top of the cap nut, and the other end connects with a passage that runs down alongside the reversing-valve bushing *19* and thence into top of steam cylinder *3*. This port, in conjunction with the passage, serves two purposes: it prevents both a back pressure and also a vacuum from forming in the cap nut above the end of the reversing rod as the latter works up and down; and it also allows steam to work through from steam cylinder *3*, and thus supply the necessary lubrication for the rod end. *36*, *37*, *38*, and *39* are copper gaskets, forming the joints between the cylinders, heads, and centerpiece, as shown. *41* is a drip cock

that should be opened when the pump is first started, to get rid of any condensation. *56*, *56* are the gland nuts.

33. Operation of Steam Cylinder.—When the pump is not working, there is a tendency for the steam and air pistons and also the main valve and reversing valve to settle down to their lowest positions.

When the pump throttle is first opened, steam enters chamber *m* and exerts an upward pressure on piston *7*, and a downward pressure on piston *7'*. Since the area of piston *7* is greater than that of piston *7'*, the steam pressure would force the main valve upwards, were it not for the fact that steam from chamber *m* passes through port *h* into chamber *l* in the valve bushing *19*, and thence through port *a* into chamber *d* above the reversing piston *23*. The downward pressure that the steam exerts on piston *23* is transmitted through its stem to the main valve *7''*, and it thus balances the upward push of the steam in chamber *m* on piston *7*, as both pistons are nearly the same size, and are acted on by the same steam pressure. The two upper pistons *23* and *7* being thus nearly balanced, the downward pressure acting on the small piston *7'* suffices to hold the main valve down in the position shown. While in this position, steam from chamber *m* passes through the lower admission ports *s'* into the steam cylinder underneath piston *10*, forcing it up. Any steam that is above the piston *10* passes through the exhaust port *e* of bushing *25*, thence on into the exhaust passage *ff* across the top head of the pump, as shown by the dotted lines, into the chamber *g* and out to the exhaust at *Y*. Just before piston *10* reaches the end of its upward stroke, the reversing plate *18* strikes the shoulder *j* on the reversing rod *17*, and the rod and reversing valve *16* are moved upwards until the valve *16* closes port *a*, and, by means of the cavity *i*, connects the exhaust port *b* with port *c*. The steam above the reversing piston *23* now exhausts through port *b*, exhaust cavity *i*, and port *c*, thence through the exhaust passage *ff* into chamber *g*, and out at *Y*. The pressure is thus exhausted from chamber *d*; and, as the upward force exerted by piston *7* of the main valve is greater than the downward force exerted by piston

7′, the main valve moves upwards, closing ports *s′* and *e*, and opening ports *s* and *e′*. Steam from chamber *m* then passes through the steam ports *s* into the steam cylinder above piston *10*, which, consequently, is forced downwards. The steam below piston *10* passes out through the exhaust ports *e′* in bushing *26*, through the passage *f′ f* into *g*, and thence out of the exhaust at *Y*.

Just before piston *10* reaches the end of its downward stroke, the under side of the reversing plate *18* strikes the button *u* on the end of the reversing rod *17*, and the reversing valve *16* is moved down to the position shown. This closes the exhaust port *b*, and opens the steam port *a*, admitting steam once more from chamber *l*, through port *a* into chamber *d*. The combined downward pressure on the reversing piston *23* and the piston *7′* is now greater than the upward force acting on piston *7*, and the main valve moves down, so that steam from chamber *m* is again admitted through ports *s′* into the cylinder below piston *10*, forcing it upwards once more, the ports *e* exhausting the steam from above the piston. This completes a full stroke in the steam end of the pump.

THE AIR CYLINDER.

34. Description.—In the **air cylinder**, as shown in Fig. 5, *31* and *33* are the receiving valves; *30* and *32* are the discharge valves. The port *p′* leads from the bottom end of the air cylinder to the space between the valves *32* and *33*, and port *p* leads from the top end of the air cylinder to the air space between valves *30* and *31*. The space *t* above the top discharge valve *30* is in direct connection with chamber *w*, by means of a passage in the body of the cylinder, which enters this chamber at *r*. Air enters the lower end of the cylinder through the air inlets in the lower valve-chamber cap *34*, and air for the upper end of the cylinder enters through the air inlets *v*, just below the receiving valve *31*.

35. The **receiving valves** should have a lift of $\frac{1}{8}$ inch, and the **discharge valves** one of $\frac{3}{32}$ inch. The lift of the

valve *30* is regulated by the distance between it and the cap nut *29*; the lift of valve *31* is regulated by the distance between the top of itself and the bottom of valve *30*; the discharge-valve stop *44* regulates the lift of valve *32*, and is itself held in position by the setscrew *45*. The lift of valve *33* is regulated by the distance between itself and the bottom of valve *32*; *40* is the oil cup through which the air cylinder may be oiled. If the cup is filled and the cock opened *while piston 11 is descending*, the oil will be drawn in; or, oil may be poured in when the pump is idle.

36. Operation of Air Cylinder.—As the steam piston is forced up and down, the air piston *11* is carried with it. When the air piston *11* is on its up stroke, the air above the piston is compressed and the tendency is to form a partial vacuum below the piston. The air compressed above the piston passes through port *p p* and in between the valves *30* and *31*, forcing the latter on to its seat and, as soon as the pressure beneath valve *30* is greater than the main-reservoir pressure on top of it, forcing this valve from *its* seat, and flowing into space *t*, thence into port *r* and down into chamber *w*, from whence it passes out at *Z* into a pipe leading to the main reservoir. Main-reservoir pressure in chamber *w* is holding the lower discharge valve *32* on to its seat, and just as soon as the partial vacuum under piston *11* (due to its upward movement) is sufficiently great, the pressure of the atmosphere forces the lower receiving valve *33* from its seat and passes through port *p'* into the cylinder, filling the space beneath piston *11* with air at atmospheric pressure.

By the time the air piston has reached the top of its cylinder, the main valve will have made its upward stroke and cut off steam from the bottom side of steam piston and admitted it to the top, thus reversing the motion of the steam piston and, therefore, of the air piston also. As the air piston moves downwards, it tends to form a partial vacuum behind it, and to compress the air in front of (i. e. beneath) it. The air that is being compressed below the piston passes through port *p'*, forcing the receiving valve *33* to its seat, and, as soon as the

pressure beneath the lower discharge valve *32* is greater than the (main-reservoir) pressure in chamber *w* above it, forcing this valve from its seat and flowing into chamber *w* and out to the main reservoir at *Z*. As already mentioned, a partial vacuum has been formed in the space above piston *11* and in port *p p*, and atmospheric pressure forces air in to fill this space, entering the holes at *v*, and raising the top receiving valve *31* from its seat, thence passing through port *p p* and filling the upper part of the air cylinder with air at atmospheric pressure. The motion of the pump is again reversed as the piston nears the bottom of the cylinder, and, in moving upwards, it compresses the air that has just been "sucked in" above the piston and forces it into the main reservoir. A complete cycle of the movements of the pump has now been traced.

THE 9½-INCH AIR PUMP.

37. As the custom of equipping freight cars with the air brake became more and more general, an engineer often found himself called on to handle 60 or more air-brake cars in a single train; it therefore became imperative that a pump of greater capacity than the old 8-inch pump should be employed. To meet this demand, the *9½-inch air pump* was brought out.

38. Three views of the Westinghouse **9½-inch air pump** are given in Fig. 6. (*a*) is a cross-sectional view, showing the front half of the pump removed; an additional portion of the centerpiece and air cylinder *x y z* is also shown broken away, so that a view of the discharge air-valves, valve cases, and air passages may be presented. (*b*) is a side view, showing a section through the valve gear in the upper steam-cylinder head; a portion of the steam cylinder also is shown broken away. (*c*) is a back view, in which portions of the steam and air passages and of the air-valve cases are broken away to give a clearer idea of the location of the valves, ports, and passages. The steam-supply pipe is connected to the pump at *X*, the exhaust pipe at *Y*, and the air-discharge pipe to the main reservoir at *Z*.

THE STEAM CYLINDER.

39. Description.—In Fig. 6, *61* is the *steam cylinder* and *63* the *air cylinder*. The steam piston *65* and air piston *66* are connected by piston rod *65'*, the upper part of which is hollow, as in the 8-inch pump. In the 9½-inch pump, all the steam valve gear, except reversing rod *71*, is contained within the upper steam-cylinder head *60*. This is a great convenience, for, should the valve gear get out of order, a new head can be substituted for the defective one in a few minutes.

Three views of the **main-valve bushing** *75* are given, namely, a longitudinal section in view (*a*), a transverse section in view (*b*), and an outside elevation in view (*d*), showing the bushing removed from the steam-cylinder head. In this latter view is also shown the main-valve head *85*. The ports *b* and *c* pass through the bushing, and are the steam ports for the steam cylinder, views (*a*) and (*b*). The port *d* also passes through the bushing, and is the exhaust port for the steam cylinder. The groove *f'* connects with the exhaust port *d*. Grooves *h'* and *g'* connect with the ports *h''* and *g''*, which open into chamber *B*, the space between piston *77* and the cylinder head *84*. A passageway *t* in the bush and *t'* in the main-valve head *85* (represented by dotted lines) establishes communication between chamber *E* in the main-valve head and the exhaust groove *f'*; chamber *E*, therefore, is in constant communication with the atmosphere through passages *t'* and *t*, groove *f'*, and exhaust port *d*. Any steam that may leak past the piston *79* is thus prevented from accumulating in chamber *E*, where it would prevent the main valve *76* from taking a stroke to the left. The port *a''* connects chamber *A*—the space within the bushing *75*—with the steam-supply passage *a' a*, views (*b*) and (*c*); consequently, this chamber, which acts as a steam chest for the slide valve *83*, is always filled with steam as long as steam is turned on to the pump. Port *e* connects with the passage *e'*, which leads into the reversing-valve bushing *73*; therefore, this bushing, which acts as a steam chest for the reversing valve *72*, is also filled with steam as long as the pump is supplied with it.

(c)

(b)

(a)

Fig. 6.

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The steam port *b* in bushing *75* connects with the steam passage *b′ b″*, which opens into the lower end of the steam cylinder below the piston at *b‴*, views (*a*), (*b*), and (*c*). The other steam port *c* connects directly with the upper end of the steam cylinder through the passage *c′*. The exhaust port *d* connects with the passage *d′ d″*, views (*a*) and (*c*), which leads to the atmosphere through the exhaust connection *Y*.

40. Steam enters the pump at *X*, flows through the passage at *a a′*, views (*b*) and (*c*), and enters the main-valve bushing through the port *a″*. Three ports *f*, *h*, and *g*, in the reversing-valve bushing *73*, connect directly with the grooves *f′*, *h′*, and *g′*, in the main-valve bushing *75*, views (*b*) and (*d*). A reversing valve *72*, having a cavity *i* in its face, operates inside the bushing *73*. The duty of this valve is to admit steam to, and exhaust steam from, the space *B* between the piston *77* and head *84*, immediately before the piston valve *76* takes its stroke toward the left or right, respectively. The reversing valve *72* is held between two shoulders on the reversing rod *71*, so that if the rod is moved up or down, it moves the valve with it, as in the 8-inch pump. When the reversing valve is in the position shown in view (*b*), it closes port *g*, and the cavity *i* connects port *f* with port *h*; hence, chamber *B* is open to the atmosphere, and any steam in there can exhaust through port *h″*, groove *h′*, port *h*, cavity *i* in slide valve, port *f*, groove *f′*, and exhaust port *d*. When the reversing valve is moved up to its highest position, port *g* is open and the part *k* of the valve covers ports *f* and *h*. Steam can now flow through port *g*, groove *g′*, and port *g″* into chamber *B*, whence it cannot escape into the exhaust, owing to the ports *f* and *h* being closed.

41. The **main valve** *76* consists of two pistons *77* and *79* of unequal diameter, connected by the valve stem *81*. The small piston *79* works to and fro in the main-valve head *85*, piston *77* working in the main-valve bushing *75*. The slide valve fits between two shoulders on the main-valve stem *81*, and, therefore, whenever the piston valve moves, it carries the slide valve with it.

42. It is thus seen that this pump contains three steam valves: the main slide valve *83*; the main valve *76*, called a differential piston valve; and the reversing valve *72*. The duty of the slide valve *83* is to regulate the admission of steam to, and the exhaust of steam from, the upper and lower sides of the piston *65*, as required. It is a valve of the ordinary D type, and is similar to the slide valve of a locomotive; however, as in the case of the latter valve, some means must be provided for moving it back and forth as required, and it is the duty of the main valve *76* to so move it.

The duty of the **reversing valve** *72* is to admit steam to chamber *B* when the main valve is to make a stroke to the left (i. e. as viewed in the illustration) and to exhaust the steam therefrom when the main valve is to make a stroke to the right. If the steam is exhausted from chamber *B*, the main valve will naturally take a stroke to the right, since the steam in chamber *A*, which acts on both pistons, exerts a greater force on the larger piston *77*. To make the main valve take a stroke to the left, it is necessary to admit steam into chamber *B*; this acts against, and balances, the pressure exerted on piston *77* by the steam in chamber *A*, and the pressure of the steam on the small piston *79* will then move the main valve to the left.

43. Operation of Steam Cylinder.—When the pump is at rest, the pistons *65* and *66* generally settle to the bottom of their cylinders, and the reversing plate *69* strikes against the button *u* on the reversing rod *71* and pulls the reversing valve *72* down into the position shown in view (*b*). As soon as steam is admitted to the pump, it enters chamber *A* in the main-valve bushing, forces the main valve to the right, as shown in view (*a*), passes down through port *b* and passage b' b'', views (*a*) and (*c*), and enters the cylinder below piston *65* through the ports b''', forcing the piston upwards. Any steam that may be above the piston *65* will exhaust through the passage c', port *c*, the cavity in the slide valve, port *d*, passage d' d'', and out at *Y*. As the steam piston *65* nears the end of its upward stroke, the top of the reversing plate *69* strikes the shoulder *j* on the reversing rod *71*, and forces reversing

valve *72* upwards until it opens port *g*, and the part *k* of the valve covers ports *h* and *f*. This permits steam to enter chamber *B* and balance the pressure on piston *77* of the main valve, and the pressure on piston *79* then forces the main valve, and with it the slide valve *83*, to the left until the cavity of the slide valve *83* connects port *b* with exhaust port *d*. When the slide valve is in this position, the steam port *c* is uncovered and steam from chamber *A* flows down through the passage $c\,c'$, into the steam cylinder above the steam piston, forcing the piston downwards. The steam below the piston then flows through the ports b''', up through passage $b''\,b'$ and port *b*, views (*a*) and (*c*), through the cavity in the slide valve, down through port *d* and passage $d'\,d''$, and out of the exhaust at *Y*. As the piston nears the end of its downward stroke, the bottom of the reversing plate *69* strikes the button *u* on the reversing rod *71* and pulls the rod and reversing valve downwards to the position shown in view (*b*). This movement of the valve, as already explained, exhausts the steam from chamber *B*, and allows the piston valve *76* to move the slide valve to the right into the position shown, thus permitting steam to pass underneath piston *65* and force it upwards. What next occurs, during the upward stroke, has already been explained. The reversing cap nut *74*, which acts as a guide for the reversing rod *71*, has a passage *x* that connects with another passage leading into the upper end of the steam cylinder. As in the 8-inch pump, this passage prevents either a back pressure or a vacuum from forming in the cap nut, and it also admits steam above the reversing rod, thus insuring a certain amount of lubrication for the rod end. Two drain cocks *105* and *106*, located in the steam passages b'' and *a*, are provided for the purpose of removing condensed water. They should be opened when the pump is first started and kept open until it is thoroughly warm. *96*, *96* are the gland nuts by means of which the piston-rod packing is adjusted.

THE AIR CYLINDER.

44. Description.—A side view of the *air cylinder 63* is shown in view (*b*) Fig. 6; a rear view will be seen in (*c*); while view (*a*) shows the cylinder with the front half removed and a portion of the rear half broken away, so as to show the discharge air-valves and passages. The piston *66* is broken away at *a b* so that port *p*—where passage *p'* enters the air cylinder—may be seen. The receiving air valves are contained within the valve cases *C* and *D*. The lift of both the receiving and discharge valves of this pump should be $\frac{3}{32}$ inch. Air enters the upper end of the cylinder through ports *m*, and the lower end through ports *n*. The air leaves the upper end of the cylinder through ports *r*, and the lower end through ports *p*, passing in each case into chamber *G*, and thence out through *Z* to the main reservoir. An oil cup *98* is provided, through which oil may be supplied to the air cylinder. Oil may be poured through this cup while the pump is standing still, or it may be filled and the cock opened when the air piston is on its *downward* stroke; the partial vacuum in the upper end of the air cylinder will then cause the oil to be forced into the cylinder by the atmospheric pressure.

45. To remove the top steam-cylinder head *60*, it is necessary to raise the steam piston *65* in its cylinder until the reversing rod *71* can be disengaged from the piston and reversing plate. In order that the pistons may be easily raised, the plug *112* in air-cylinder head is provided on a number of pumps. A bar can be used through this opening, and the pistons raised very readily. This plug opening is useful in other ways also, as it enables the lower end of the air cylinder to be cleaned and the piston-rod nuts to be inspected. The pipe to the main reservoir is connected at *Z*, and main-reservoir pressure, therefore, is always acting to hold valves *87* and *87'* on their seats; to unseat them, the pressure below the valves must be greater than main-reservoir pressure.

46. Operation of Air Cylinder.—When the air piston *66* makes an upward stroke, it causes a partial vacuum to be

formed below it, while the air above is compressed. Air then flows in through the screened inlet *W*, and passes downward through the passage *F*, view (*c*), then through the receiving valve *86'* and ports *n*, as shown by the arrows, into the lower end of the air cylinder, filling it with air at atmospheric pressure. In the meantime, the air that is compressed above the piston holds receiving valve *86* on its seat, and passes out through ports *r* and the passage *r'* to the under side of discharge valve *87*, and, as soon as its pressure exceeds that in the main reservoir, raises valve *87* and flows through the passages *s* and *G* and out at *Z* to the main reservoir, as shown by the arrows. On the downward stroke of the air piston, a partial vacuum is formed above, and the air is compressed below it. Air then flows in through *W* and passes up the passage *F*, through receiving valve *86* and ports *m*, and fills the upper part of the cylinder with air at atmospheric pressure.

As the air is compressed below the piston, it holds receiving valve *86'* on its seat, and passes out through ports *p* and passage *p'* to the under side of discharge valve *87'*, and, as soon as it exerts a pressure slightly greater than main-reservoir pressure, opens valve *87'* and passes up through passage *G* and out at *Z* to the main reservoir.

THE PLAIN TRIPLE VALVE.

GENERAL REMARKS.

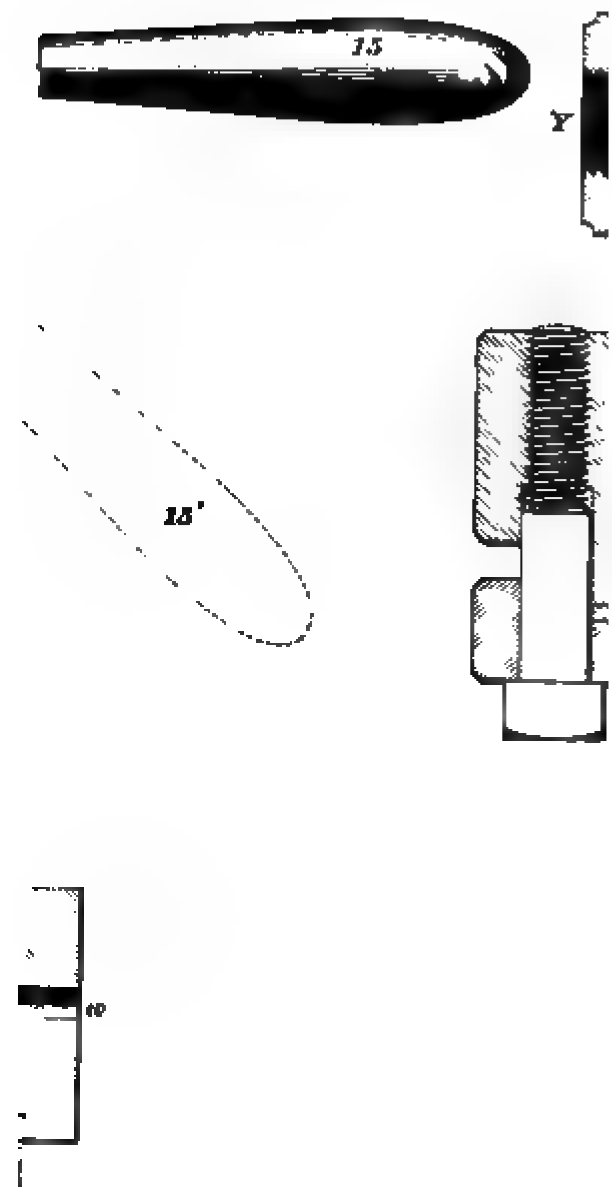
47. As mentioned in the introductory portion of this Section, the straight-air brake was in due time supplanted by the automatic brake. The essential part of the new style of brake was the triple valve, now known as the **plain triple valve,** to distinguish it from a later form known as the *quick-action triple valve,* to be described later. The plain triple is still in use on engines and tenders, and also on some of the very early car equipments. It is practically the same as the **service part** of the present quick-action triple, that is, the part of the latter that is used in making a service application of the brakes. These two kinds of triples are somewhat

differently constructed, but the results, actions, and parts employed in making a service application of the brakes are practically identical in each case. When the plain automatic triple was introduced, a great many cars were equipped with the straight-air brake, and it was necessary to so construct a triple valve that, if put in a train with a number of straight-air cars, the automatic feature of the triple could be cut out, and the brakes on that car used "straight air," as on the other cars.

DESCRIPTION.

48. In Fig. 7 are shown cross-sectional views of the plain triple valve introduced to accomplish the above purpose. The plug valve *13*, which effects the required changes, is actuated by the handle *15*. This handle may be placed in any one of the three positions *15*, *15'*, or *15''*, shown in the cut. As it now stands, in position *15*, the triple can be used with the automatic brake. When the handle stands in position *15'*, the plug valve *13* is moved so that the portions *p*, *l*, and *i*, of the plug cover the ports *a*, *f*, and *d*; the brake is then cut out entirely on that car. With the handle in position *15''* pointing downwards, the passage *e* in valve *13* connects port *a* with port *d*, thus enabling the triple to be used in the straight-air system. However, now that the straight-air brake is a thing of the past, a lug, not shown in the figure, is cast on the handle *15*, which prevents the handle from being turned to position *15''* to convert the brake into "straight air."

49. The other parts of the triple valve, as numbered in the figure, are: *1*, the triple body; *2*, the drain cup; *3*, the triple slide valve; *4*, the slide-valve spring; *5*, the triple piston; *6*, the triple-piston packing ring; *7*, the graduating valve; *8*, the upper cap nut; *9*, the graduating stem; *10*, the graduating spring; *11*, the graduating-stem nut; *12*, the cylinder-cap gasket. The space *C* is called the slide-valve chamber; *g* the exhaust cavity in the face of the slide valve *3*; *k* the triple exhaust port; *m* is a small feed groove in the piston bushing; and *n* is a groove in the shoulder of the triple piston itself. These grooves *m* and *n* allow air from the train line to



(a) (b)

Fi

W

a. 7. (c) (d)

feed into the auxiliary reservoir when the triple piston is in release position. This piston *5* is acted on by pressure on both sides of it, moving away from the greater pressure when the two pressures are unequal, or remaining stationary when these pressures are equal. The branch pipe from the train line connects with the triple at *W*; the pipe leading from the brake cylinder connects at *X*, while the connection to the auxiliary reservoir is made at *Y*. In the tender equipment, Fig. 1, is shown a plain triple valve connected to the auxiliary reservoir, brake cylinder, and train line. Chamber *C*, as will be evident on studying the figure, is always charged with auxiliary pressure, and chamber *B* with train-line pressure, the piston *5* marking the line of separation between the two. The piston *5* may be moved up or down by increasing or decreasing the pressure in chamber *B* above or below that in chamber *C*. The packing ring *6* is made a good fit in the bushing, so that when the piston has moved down far enough to cover the groove *m*, air cannot readily pass by it in either direction.

ACTION OF PARTS.

50. The automatic portion of the mechanism of the plain triple consists of the slide valve *3*, graduating valve *7*, piston *5*, and graduating stem *9*. A sectional view of the slide valve *3*, showing the graduating valve and ports, is given in view (*b*). The port *w* passes through the slide valve from one side to the other. When the **graduating valve** *7* is off its seat, auxiliary air can flow through port *w* past the valve and out at *z*, but when the valve is on its seat, no air can escape through port *z*. Besides ports *w* and *z*, there is an exhaust cavity *g* in the face of the valve, as seen in view (*a*). The slide valve is surrounded by air at auxiliary pressure, which holds the valve to its seat. The spring *4* is provided to hold the valve to its seat when there is no auxiliary pressure to perform this duty, thus preventing dirt from collecting on the valve seat and affecting the working of the triple.

The piston *5* controls the movements of both the slide valve and the graduating valve. The slide valve fits loosely between

shoulders on the piston stem, and, when the piston moves far enough, it carries the slide valve with it. The graduating valve *7* is connected to the stem of piston *5* by means of a small pin, shown in view (*a*), the place where it enters the pin and stem being shown by dotted lines; thus, the graduating valve is fixed with respect to the piston *5* and moves along with it. The length of the slide valve *3* is purposely made less than the distance between the shoulders on the piston stem, so that the piston in moving downwards will open, or, in moving upwards will close, the graduating valve *7*, before it moves the slide valve *3*. When the slide valve is in service position, the piston *5* can move up and down far enough (about $\frac{5}{32}$ inch) to operate the graduating valve without disturbing the slide valve. We thus see that the piston may move a limited distance without moving the slide valve; whereas, the graduating valve, being secured to the piston stem by the small pin referred to above, must move with the piston.

51. The graduating stem *9* is held in position by the graduating spring *10*. When a gradual, or service, reduction of train-line pressure is made, the pressure in chamber *B* is reduced below that in chamber *C*, and auxiliary pressure then moves piston *5* down until its knob *j* touches the graduating stem *9*, when the spring *10* prevents its moving any farther. When a sudden and heavy reduction of train-line pressure is made, as in emergencies, a sufficient difference of pressures is established in *B* and *C* to cause piston *5* to move down quickly and compress spring *10*, the piston traveling the whole length of chamber *B* until it bottoms on the lower end.

The graduating nut can be removed when it is desired to drain the triple or to examine the graduating stem and spring. *w* and *z* form one continuous port through the slide valve *3*, as already explained in connection with view (*b*); this port is opened and closed by the graduating valve *7*, and is called the **service, or graduating, port.** When the triple is in *service position*, air from the auxiliary reservoir flows through the slide valve by means of this port, thence into port *f* and on through port *d* into the brake cylinder.

DUTIES OF THE TRIPLE VALVE.

52. The triple valve has three duties to perform: (1) to charge the auxiliary; (2) to apply the brakes; and (3) to release the brakes.

When an engine is coupled to a car, air from the main reservoir flows back into the train pipe, thence through the branch pipe (as shown in Fig. 1), entering the triple at *W*. When the triple is "cut in," the air can flow in at *W*, and on through ports *a*, *b*, *c* into chamber *A*, whence it passes into chamber *B*. If piston *5* were down, the air entering chamber *B* would force it up into release position, as shown in Fig. 7 (*a*). The feed groove *m* is now open, and air therefore feeds from chamber *B* past piston *5*, through the grooves *m* and *n* into the slide-valve chamber *C*, which communicates through *Y* with the auxiliary reservoir. The air continues to feed past piston *5* as long as train-pipe pressure in chamber *B* is greater than the auxiliary pressure in chamber *C*. The usual train-pipe pressure is 70 pounds, and, when the auxiliary pressure has reached this amount, the pressures in chambers *B* and *C* are equal, and the auxiliary is said to be fully charged. The lower side of piston *5* is generally referred to as the "train-pipe side," and the upper as the "auxiliary side," or the "slide-valve side."

53. Charging Auxiliary Reservoir.—A modern triple valve should charge an auxiliary from zero up to 70 pounds in about 70 seconds, with a constant train-pipe pressure of 70 pounds. With the triple in release position and the auxiliary charged, there will be 70 pounds in the train pipe, 70 in the auxiliary, and no pressure at all in the brake cylinder, since the slide-valve cavity *g* connects the brake cylinder with the atmosphere, the communication being through the ports and passages *d*, *e*, *f*, *g*, *h*, and *k*.

54. Applying Brakes.—To apply brakes, it is necessary for a train-pipe reduction to be made. This may be made (1) in the usual way by the engineer, (2) by the use of the conductor's valve, or (3) by a break-in-two, a burst hose, or a heavy leak in the train pipe.

If the engineer makes a reduction of 7 pounds in the train pipe, only 63 pounds will remain in chamber *B*, whereas at the beginning of the reduction, there will be 70 pounds in chamber *C*, or the auxiliary side of piston *5*. This greater auxiliary pressure will force piston *5* downwards. While being forced down, it first closes the feed groove *m* and unseats the graduating valve *7*, allowing auxiliary air to enter the slide valve at *w* and pass through to the end of port *z*. The air, however, cannot pass out of port *z* until the slide valve is moved to service position. By the time the graduating valve is unseated and the feed groove *m* closed, the shoulder *14* on the upper end of the piston stem has engaged the slide valve and begun to move it down. As the slide valve moves down, the exhaust cavity *g* is closed to the ports *f*, *e*, and *d* leading to the brake cylinder. When the knob *j* touches the graduating stem *9*, the piston *5* is prevented from making any further downward movement. With the triple piston in this position, the service port *z* of the slide valve is directly in front of port *f*. This position of the valve is called the *service position*, and is shown in Fig. 7 (*c*). The graduating valve being off its seat, there is now an open communication between the auxiliary and the brake cylinder, and air flows from the auxiliary through the ports *w* and *z* in the slide valve, thence through the ports *f*, *e*, *d*, and out at *X* into the brake cylinder, where the pressure will force out the brake piston and set the brakes. Just so long as the auxiliary pressure is greater than that in the train pipe, so long will piston *5* be held down and the graduating valve remain unseated; but the auxiliary pressure gradually expands into the brake cylinder, until the pressure in chamber *B* is sufficiently greater than that in chamber *C* to overcome the small friction of the packing ring *6*, and cause piston *5* to move upwards and seat the graduating valve, thereby closing port *w*. The pressure on the train-pipe side of the piston *5* still slightly exceeds that in the auxiliary, but not to such an extent as to overcome the additional friction encountered in moving the slide valve *3*; the piston therefore stops as soon as the graduating valve has been seated. This is called the *lap position* of the triple valve, in which position all ports are blanked. The

brakes are now partially set; a further train-pipe reduction will be necessary to apply them any harder.

If another 5-pound train-pipe reduction is made, the greater auxiliary pressure again forces the piston down, but in this case the slide valve was already in service position to begin with, and it is only necessary to move the piston down sufficiently to unseat the graduating valve. This is accomplished by the time the knob *j* touches the graduating stem *9*; and once more, by means of the service port of the slide valve, communication is established between the auxiliary and the brake cylinder. The graduating valve is again seated automatically by the piston *5* when the auxiliary pressure becomes a little less than that in the train pipe.

After the slide valve has once been moved down, it remains in service position until the brakes are released. Each reduction of train-pipe pressure causes the brake to set harder, and these reductions may be continued just as long as the pressure in the auxiliary is greater than that in the brake cylinder. When these pressures become equalized, the brake is fully set, and a further train-pipe reduction would be a waste of air. Ordinarily, a train-pipe reduction of about 20 pounds will cause a full application of the brakes.

55. Releasing Brakes.—To release brakes, the engineer allows the air stored in the main reservoir to feed quickly into the train line. When the pressure on the train-pipe side of piston *5* is sufficient to overcome auxiliary pressure and the friction of the working parts, the piston is forced upwards to *release position*, carrying the graduating and slide valves with it. In this position, Fig. 7 (*a*), the feed groove *m* is opened, and air from the train pipe feeds through *m* and *n* to recharge the auxiliary. At the same time, the pressure in the brake cylinder escapes through *X* and ports *d*, *e*, *f*, *g*, *h*, and *k* into the atmosphere.

56. Emergency Application.—To apply brakes in an emergency, it is necessary to make a sudden and heavy train-pipe reduction. This sudden reduction causes piston *5* to move down very quickly and, compressing the graduating spring *10*,

to traverse the full length of chamber *B*. In this position, a direct connection is established between the auxiliary and brake cylinder across the upper end of the slide valve *S*, as shown in Fig. 7 (*d*). Auxiliary air passes direct into ports *f*, *e*, *d* and out into the brake cylinder at *X*, without having first to pass through the service ports of the slide valve. As only the large ports are used in *emergency position*, they allow the pressure in the auxiliary and brake cylinder to equalize more quickly than do the smaller ports used in the service position. With a plain triple, the brake sets *more quickly* in emergency, but *not with greater force*.

To get the full emergency action of the brakes with plain triple valves, it is necessary to make a sudden reduction of about 20 pounds in train-pipe pressure. After an emergency application, the release of the brakes is accomplished in the same way as after a service application, already described.

THE QUICK-ACTION TRIPLE VALVE.

GENERAL REMARKS.

57. **The quick-action triple valve** is automatic in its action and can be used on a train of which some of the cars are fitted with the plain triple, but it cannot be worked "straight air," as can the plain triple, for when the triple valve is cut out, the communication from the train pipe to the brake cylinder is also cut off.

Fig. 1 shows the arrangement (on a passenger car) of the quick-action triple, auxiliary reservoir, brake cylinder, and connections. A T drain cup is inserted in the train pipe; a branch pipe extending from this T piece connects with the triple, as shown.

In this branch pipe is a stop-cock *6*, by means of which the brake on that particular car can be cut out or in, as desired, without interfering with the brakes on the rest of the train. When the handle of this cock stands at right angles, or crosswise, to the branch pipe, the brake on that car is cut in, that is,

it can be operated from the engine in the ordinary manner. When the handle is turned so as to be parallel to, or in line with, the pipe, the brake on that car is cut out, or is inoperative.

Fig. 8 shows the triple connected to the brake cylinder, this illustration being on a larger scale than Fig. 1. The branch pipe from T piece connects with the triple at *W*. The opening *d* of the triple valve communicates with the passage *P* in the cylinder head, through which passage air is conducted to and from the brake cylinder. The opening *Y* connects with a pipe *8* leading to the auxiliary reservoir, through which pipe the air is conducted between the auxiliary and the triple.

DESCRIPTION.

58. The parts of the quick-action triple as numbered and lettered in Fig. 9 (*a*) are: *1*, the drain cup; *2*, the triple body; *3*, the slide valve; *4*, the slide-valve spring; *5*, the triple piston, and *6*, its packing ring; *7*, the graduating valve; *8*, the emergency-valve piston; *9*, the emergency-valve seat; *10*, the emergency valve, also commonly known as the rubber-seated valve; *11*, the rubber seating; *12*, the check-valve spring; *13*, the check-valve case; *14*, the check-valve case gasket; *15*, the check-valve; *16*, the train-pipe strainer, which keeps foreign substances from entering the triple; *17–18–27*, a union joint; *20*, the graduating-stem nut; *21*, the graduating stem; *22*, the graduating spring; and *23*, a leather gasket. The branch pipe from the train pipe connects at *W*; the pipe to the brake cylinder connects at *X*; the auxiliary-reservoir connection is made at *Y*; *m* and *n* are the feed grooves; and *t* is the port through which auxiliary pressure passes to the space above emergency piston *8* to operate the emergency valve *10*.

59. The quick-action triple contains two distinct sets of mechanism. One of these, consisting of the triple piston *5* with stem, slide valve *3*, and graduating valve *7* with stem *21* and spring *22*, is used in making service stops and in releasing brakes; it is often called the *service part* of the triple. The other set, consisting of the emergency piston *8*, emergency

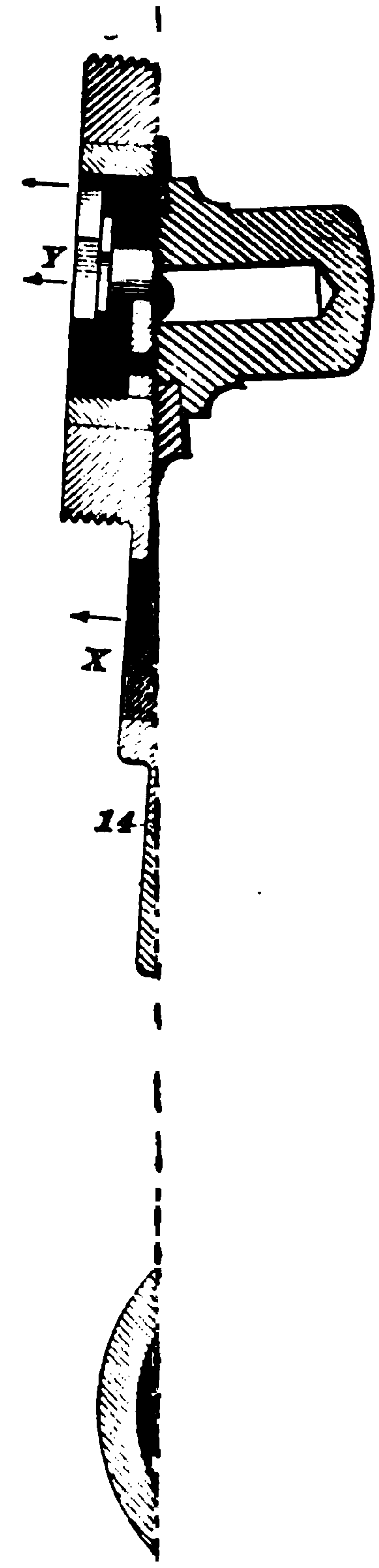
valve *10*, and train-pipe check-valve *15*, is only brought into use in an emergency application of the brakes; it is hence often called the *emergency* or *quick-action part* of the triple.

SERVICE PART OF TRIPLE.

60. Description.—The description and mode of action of the **service part** of the plain triple applies also to that of the quick-action triple, except in so far as the slide valves *3* differ somewhat in detail. As in the case of the plain triple, the stem of piston *5* engages with slide valve *3*, and also operates the graduating valve *7*. The service ports *w* and *z* in the valve *3* are the same as in the plain triple, but this valve contains, in addition, an emergency port *s*; also, the valve is longer, and one of its edges or corners is cut away, as shown at *q* in Fig. 9 (*b*). This latter view represents the valve as transparent, so as to show the ports better, and it is turned upwards so as to show the exhaust cavity *g* in its face; *w* and *z* are the service ports controlled by the graduating valve *7*; *s* is the emergency port, the end *s'* of which is smaller than port *z*; *q* is generally referred to as the **removed corner** of the valve. Cavity *g*, and ports *w*, *z*, and *s* are shown also in Fig. 9 (*a*). The port *f*, with passages *e e'* and *d*, leads to the brake cylinder; port *t*, as already mentioned, leads to the space above emergency piston *8*; and exhaust ports *h* and *k* lead to the atmosphere. The ports *f*, *t*, *h*, and *k* are also shown in view (*c*), which is a view of the valve seat *24*.

When the slide valve is in emergency position, the removed corner *q* allows auxiliary air to pass down through port *t* and force piston *8* downwards. This unseats emergency valve *10*, and opens communication between the train pipe and the brake cylinder; the check-valve *15* is then raised by train-pipe pressure and allows train-pipe air to pass to the brake cylinder.

61. Rubber-Seated Valve.—The duty of the **emergency, or rubber-seated, valve** is to prevent the train-pipe air from passing into the brake cylinder through chamber *I* and port *d*, except when required to do so in emergency applications. Were it not for this valve *10*, the brakes would apply


Y
X
14

as soon as air was turned into the train pipe, and, the triple exhaust port *k* being open, there would be a constant blow through to the atmosphere.

62. Train-Pipe Check.—The **train-pipe check** *15* prevents the brake-cylinder pressure from flowing back into the train pipe, in the event of a hose bursting or the train pipe breaking, or at any time when the train-pipe pressure is less than the brake-cylinder pressure. If a hose were to burst, all the air would leave the train pipe, and the brakes on the entire train would set in full. If the train-pipe check *15* were not in the triple, there would be nothing to prevent air passing from the cylinder to the train pipe and out to the atmosphere, in case the train parted or a hose burst. This would release that brake.

Spring *12* holds valve *10* to its seat when there is no air pressure present to perform this duty, and, also, when the pressures in chambers *y* and *I* become equalized after an emergency application of the brake. It performs the same duty for train-pipe check *15*.

63. Train-pipe air entering the triple at *W* feeds through the passage *a b* and port *c*, and on through the feed grooves *m* and *n* into chamber *C*, thence through *Y* into the auxiliary. If, when air enters the triple, there is no pressure on top of the train-pipe check *15*, the air underneath will raise it from its seat against the force of the spring *12* and fill chamber *y*, forcing the rubber-seated valve *10* more firmly on its seat. When the pressure in the chamber *y* and the force exerted by the spring *12* are together slightly greater than the train-pipe pressure underneath the check-valve *15*, this valve is forced to its seat and thenceforth plays no further part unless an emergency application is made.

64. Release Position.—The slide valve of the quick-action triple is shown in release position in Fig. 9 (*a*). In this position, any air that may be in the brake cylinder can pass through passages *d* and *e′ e*, port *f*, cavity *g* of the slide valve, and the port *h*, out through exhaust port *k* to the atmosphere. Port *k* is also shown in view (*c*), as is also the

port *f* leading through the passage *e e′* to the brake cylinder, and port *t* leading to the top of the emergency piston *8*.

65. Service Position.—When a service application of the brakes is made (by gradually reducing train-pipe pressure), the triple piston *5* moves out until the knob *j* touches the graduating stem *21*, view (*d*), after which any further movement is prevented. The service port *w* and port *z* of the slide valve now connect with the brake cylinder by way of port *f* and passages *e e′* and *d*. As the graduating valve *7* opens before the slide valve moves forward, air now passes from the auxiliary reservoir through ports *w*, *z*, *f*, and passages *e e′*, *d*, to the brake cylinder until auxiliary pressure is reduced just a trifle below train-pipe pressure, when the graduating valve *7* is closed. During succeeding reductions, the graduating valve simply opens and closes without moving the slide valve, as already explained in describing the action of the plain triple.

EMERGENCY PART OF TRIPLE.

66. When, in cases of danger, etc., a sudden reduction of train-pipe pressure is made, what is termed the **emergency part** of the triple valve is called into play; the triple piston *5* moves out quickly, the graduating spring *22* is compressed, and the triple piston travels the full length of chamber *B*. This, the *emergency position* of the triple, is shown in view (*e*). In this position, port *s* in the slide valve connects with port *f* in its seat, and auxiliary pressure can pass through the ports *s*, *f*, and passages *e e′*, *d*, out at *X* into the brake cylinder. The removed corner *q* of the slide valve, view (*b*), has shortly before this reached a position directly above port *t*, view (*e*), thus allowing auxiliary air to pass down through port *t* on to the top of the emergency piston *8*, forcing it downwards. This downward movement unseats the emergency valve *10*, and allows the air in chamber *y* above the emergency check *15* to escape. Train-pipe pressure beneath this check-valve now forces the latter from its seat, and air from the train pipe passes up by it, on through chamber *y* and the unseated emergency valve *10*, into chamber *I*, and out at *X* to the brake cylinder. The

emergency valve remains unseated until the pressures in chambers *y* and *I* are nearly equalized, when the spring *12* forces the emergency valve and check-valve to their seats.

The position of the removed corner *q* on the slide valve is such that, as the valve moves forward to emergency position, it connects port *t* of the valve seat with auxiliary pressure a short time before port *s* connects with port *f*. The emergency valves therefore open before port *s*, and, consequently, train-pipe air—which passes like a flash through the large openings of the emergency valves—in sufficient quantity to give a pressure in an 8-inch brake cylinder of about 24½ pounds, when check-valve *15* closes. As soon as port *s* connects with port *f*, auxiliary pressure discharges into, and equalizes with, the brake cylinder; but, since the cylinder already contains about 20 pounds pressure, they equalize at about 60 pounds pressure instead of at 50 pounds, as in a service application.

The emergency port *s* of the slide valve is made smaller at *s'* than the service port *z*, to retard the flow of air somewhat from the auxiliary reservoir to the brake cylinder during an emergency application of the brakes, so as to allow as much air as possible to enter the brake cylinder from the train pipe, and thus increase the final brake-cylinder pressure.

67. Plain and Quick-Action Triples Compared. Comparing the plain and the quick-action triples, it will be seen that they both work exactly the same in a *service application*, but that the quick-action triple sets the brake both quicker and harder in *emergency*. The quick-action triple also sets the brake harder in *emergency* than in *service application*, owing to the emergency valve, piston, and check-valve operating so as to allow train-pipe pressure to enter the brake cylinder and aid the auxiliary pressure in applying the brake.

The plain triple sets the brake quicker in emergency than it did in service, owing to the use of larger ports; but the brake does not set any harder, since it simply has auxiliary pressure to use in applying the brakes in either service or emergency.

When a quick-action triple goes into emergency position, a sudden train-pipe reduction is made near it when the emergency

valve opens. This sudden reduction starts the next quick-action triple, and that starts the next, and so on throughout the train. If from any defect one triple goes into quick action, all will follow.

Ordinarily, a gradual train-pipe reduction of about 20 pounds will cause a plain or a quick-action triple valve to equalize the pressures between the auxiliary and brake cylinders at about 50 pounds. In emergency, with a quick-action triple, the pressures are equalized at about 60 pounds, while with the plain, the same pressure is obtained in the cylinder in emergency as in a full-service application, namely, 50 pounds. With quick-action triples, a sudden train-pipe reduction of 10 or 12 pounds will produce a full emergency action of the brakes; while, with a plain triple, a reduction of about 20 pounds is necessary. The reason for this is that a 12-pound reduction will cause the emergency valves of the first triples to open and produce a further train-pipe reduction. Train-pipe pressure is not affected in this way when a plain triple goes into emergency, and, therefore, while a sudden 12-pound reduction would force the triple to emergency position, it would not stay there, as it would be forced back to *lap* or perhaps to *release*, as soon as auxiliary pressure had reduced the 12 pounds. It is necessary, therefore, to reduce train-pipe pressure below that at which the auxiliary and brake cylinders equalize, to obtain a full emergency application with plain triples.

FREIGHT AND PASSENGER EQUIPMENTS.

68. Equipments Compared.—An illustration of the **freight-car equipment** now used is given in Fig. 10. It consists of auxiliary reservoir *10*, brake cylinder *2*, and triple valve *18*. This equipment has to be made very compact on account of the limited space for it on freight cars; but, while it appears to be different from that used on passenger cars, shown in Fig. 1, yet it is exactly the same in principle and operation.

In the **passenger-car equipment**, Fig. 8, there is a pipe *8* leading from chamber *Y* of the triple valve to the auxiliary

reservoir, whereas, in the case of the freight-car equipment, Fig. 10, the air passing from the train pipe through the triple goes direct to the auxiliary.

In the freight equipment, pipe *b* connects the triple valve *18* with the **brake cylinder,** while in the passenger equipment, the triple is fastened directly to the cylinder. When the brake is released in a freight equipment, air from the brake cylinder flows through pipe *b* and out through the triple exhaust to the atmosphere.

In the passenger equipment (Fig. 8), the piston rod is fastened to the crosshead 7, and the brake levers, also connected to the crosshead 7, are controlled by the cylinder piston, the levers being moved every time the piston moves. In a freight equipment (Fig. 10), this is not so, as a push rod, bottoming on the piston, is inserted in the sleeve *3*. The outer end of the push rod (not shown in figure) is connected to the brake levers, and, when the hand-brakes are applied, the push rod may be drawn out without moving the piston. When the air brake is applied, piston *3* is forced out, carrying the push rod with it.

There are practically no points of difference in the freight and passenger equipments other than those already described, and a description of the parts in the one will apply equally to those of the other. The various parts of the triple valve have already been described and the mode of working explained.

69. Description.—The **auxiliary reservoir** *10* (Fig. 10) is a storage reservoir. The air stored there is for use in the cylinder *2*, and its use is confined entirely to the car on which it is placed.

The release valve *17*, or **bleed cock,** as it is sometimes called, is for reducing the auxiliary pressure. If the brake on any particular car should "stick," it can be released by opening the bleed cock of the auxiliary on that car until air begins to exhaust from the triple valve, when the bleed cock should immediately be closed. Bleeding the auxiliary reduces the pressure there below that in the train pipe, which consequently forces the triple piston to *release position* and releases the brake.

The brake cylinder can be oiled by means of the oil plug *16*; there is a similar plug on the other side of the cylinder. Either may be used for the above purpose.

The piston *3* is operated by the air pressure in applying the brakes. In the top of the brake cylinder will be noticed a small groove *a*. This is known as the **leakage groove.** The triple exhaust port takes care of any air that enters the brake cylinder while brakes are released; the leakage groove is provided so that any air that enters the brake cylinder while the triple is in service position due to a very light application, will pass by piston *3* and out to the atmosphere through the open end of the cylinder. The groove is placed in the top of the cylinder (in which position it is least likely to become clogged with dirt), and is of such a length that the brake piston must move out about 3 inches before the groove is covered. Leakage grooves are now cut in the side of brake

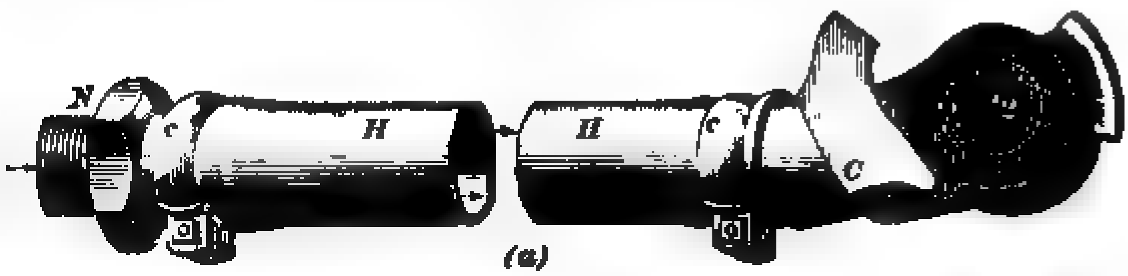
cylinders instead of at the top. Leakage grooves are found in the brake cylinders of freight and passenger cars, and also on most tenders, but not in driver-brake cylinders, until recently. *9* is the release spring; when, in applying the brakes, air enters the cylinder and forces piston *3* out, the release spring is compressed; in releasing the brake, air leaves the cylinder and the release spring forces piston *3* back to *release position*, as shown in Fig. 10. *4* is the front cylinder head; it acts as a guide for the sleeve *3*.

The cup leather packing *7* is to keep the air that enters the cylinder from passing by the piston; it takes the place of the ordinary iron packing rings used in steam cylinders. *6* is the follower plate, which holds the leather packing in place. *8* is the expander ring, which forces out the leather against the walls of the brake cylinder, and so prevents air from passing the piston. As the air enters the cylinder, it strikes the flanges of the leather, forcing them against the walls of the cylinder, and forming an air-tight joint.

TRAIN-PIPE COUPLINGS.

70. In Fig. 11 (*a*) is shown an **air-brake hose** *H* with the nipple *N* and coupling *C* attached; they are fastened to the hose by means of the clamps *c*, *c*. (*b*) is an enlarged view of the coupling *C* shown in (*a*); this is a device for coupling together the hose on two adjacent cars. (*d*) is an angle cock, one of which is attached to each end of the train pipe on each car, as seen in Fig. 1. Connection is made between hose and angle cock by means of the *hose nipple N*, shown in (*a*), which is screwed into the angle cock at *1*, the end *6* of the cock itself being screwed on to the train pipe. *2* is a plug valve operated by the handle *4*. *3* is the liner, or bushing, in which the plug *2* works; it constitutes the valve body. As the valve now stands, air can pass through it. To stop the flow of air, the handle must be placed at right angles to the position here shown. The spring *5* holds the plug tight to its seat. In views (*a*) and

(*b*), *2* is a rubber gasket, by means of which a tight joint is made when the couplings are united between two cars. (*c*) is called a **coupling hook.** The coupling *C* when not in use



(a)

(b)

6

(d)

(c)

FIG. 11.

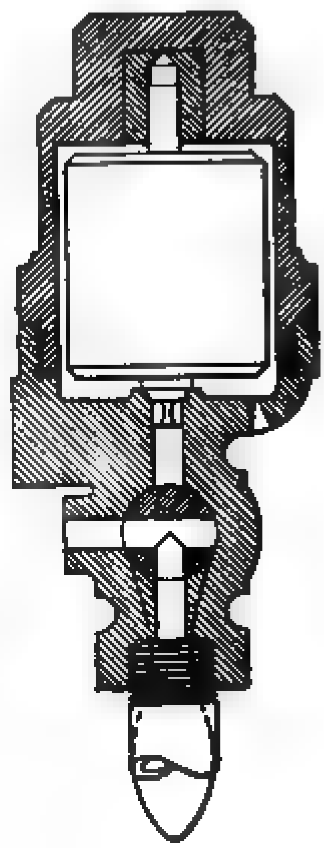
is hung in the coupling hook, instead of allowing the hose to hang down and collect dirt, snow, and cinders, which would gradually work into the triples and impair their action.

RETAINING VALVE.

71. Its Duty.—The **retaining valve**, shown in Fig. 12, is used on freight cars in all sections of the country, and on passenger cars, engines, and tenders in mountainous districts.

It is located at the end of the car, in such a position as to be within easy reach of the trainmen when the train is in motion, and is connected by a pipe at *X* with the exhaust port of the triple valve.

Its purpose is to retain a pressure of 15 pounds in the brake cylinder, in order to have sufficient braking power to keep the



(a)

(b)

Fig. 12.

speed of a train from increasing too rapidly while the engineer is recharging the train after a release on a grade, preparatory to another application of the brakes.

The retainer cap *3* acts as a guide, and keeps the weighted valve *4* from falling out. It also retards the flow of air from the brake cylinder by forcing it to pass out of the small opening at *d*. The valve *4* is of such a weight that it requires a pressure of

15 pounds per square inch in port *b'* in order to raise it. The body of the retaining valve is shown at *2*; *6* is a plug valve operated by the handle *5*.

72. Operation.—When the retaining valve is cut out, the handle *5* points straight downwards, as in view (*b*). If the triples are released with the handle *5* in that position, air from the brake cylinder will pass through the exhaust port of the triple, through the pipe connecting the triple valve with the retainer at *X*, and on through ports *b*, *a*, and *e* to the atmosphere. If, when the brakes are released, the handle *5* is in the position shown in view (*a*), the air coming from the brake cylinder and entering the retainer at *X* will pass through ports *b* and *b'* and so come in contact with the weighted valve *4*. Any pressure above 15 pounds per square inch will raise valve *4* and pass out to the atmosphere through port *d*. When the brake-cylinder pressure is reduced to 15 pounds, valve *4* reseats itself and holds the remaining pressure in the cylinder. The diameter of port *d* at the smallest part is $\frac{1}{16}$ inch. This port is made small so as to further retard the passage of air from the brake cylinder to the atmosphere. The consequence of this is that pressure accumulates in the cap *3*, which acts in concert with the weight of valve *4* to close the valve for a few seconds at frequent intervals until the pressure is reduced to 15 pounds; consequently, the brake-cylinder pressure reduces rather slowly. It takes about 20 seconds for a brake-cylinder pressure of 50 pounds, with average

FIG. 18.

piston travel, to reduce through the retainer to 15 pounds, using a modern retainer with the small port *d*.

In an earlier form of retaining valve, there were two $\frac{1}{4}$-inch holes located similarly to port *d*. These large ports allowed the brake-cylinder pressure to reduce so rapidly that the valve was not sufficiently effective on heavy grades.

Fig. 13 shows the improved retaining valve, which differs from that shown in Fig. 12 in that its plug cock *6* is held always on its seat by the spring *8*. Also, the weighted valve seats on a bushing *9*; *7* is the cap for the cock *6*; the arrangement of ports in the cock is the same as in Fig. 12. The view of this valve is as seen from the front when on the car, whereas Fig. 12 is a side view. The action of this valve is the same as the other; when the handle *5* is turned down, as in the figure, the valve is cut out; when it stands out straight (i. e. horizontally), it is cut in, and will retain 15 pounds in the brake cylinder. The port *d* is in this valve also, but is not shown in this view, owing to the manner in which the section has been taken.

The retaining valve has nothing to do with applying the brakes; it simply retains a certain amount of pressure in the brake cylinder when the triple valve goes to release position.

ENGINEER'S D-8 BRAKE VALVE.

73. The **engineer's brake valve** is that part of the air-brake equipment by means of which the engineer can control the action of the brakes. The two kinds of brake valves now in use are the D-8 and the D-5, E-6, or F-6, the latter three terms denoting one and the same valve, the letter and number being changed as each new catalogue is issued. The D-8 is gradually being supplanted by the F-6, but there are still a large number of the former in use.

74. Description.—The **D-8 brake valve** is shown in Fig. 14, views (*a*) and (*b*) being cross-sections, and (*c*) a plan view with the rotary valve and handle removed so as to show the rotary seat. View (*d*) shows the face of the rotary valve and the ports and cavities in it. View (*e*) is a horizontal section

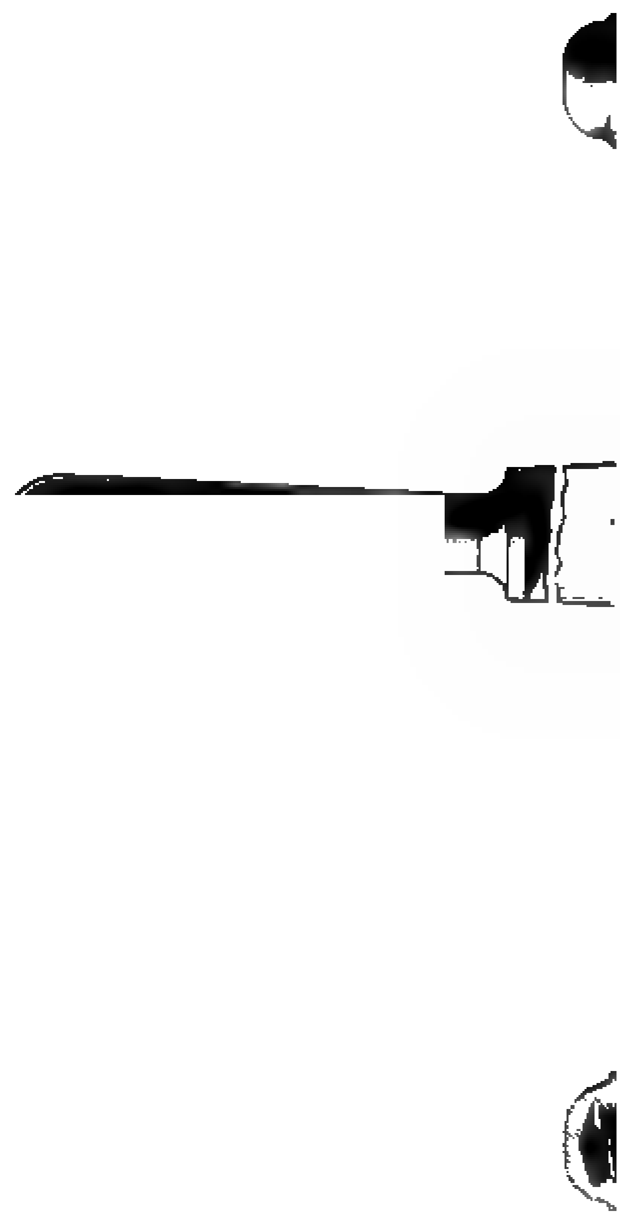
through the excess-pressure valve *21* in view (*b*). In view (*e*) is shown the passage *f′* leading from the feed-port *f* to chamber *r* on one side of the excess-pressure valve, and the passage *xf″*, which leads from the other side of the excess-pressure valve to the direct-application-and-supply port *l*.

Fig. 14 (*a*) and (*b*) and also Fig. 15 shows the **rotary valve** *13* in release position, with cavity *b* of the **rotary seat** connecting port *a* of the rotary with cavity *c*, which latter connects with port *l*.

In view (*d*), which shows the face of rotary valve *13*, *q* is a pin that fits into a hole in the rotary seat; it acts as a guide for the rotary. The supply port *a* and also port *j* pass entirely through the rotary, while *c* is a cavity in the face of the rotary, but not extending through it; *p* is a small groove in the face of the rotary. When the valve is in *service position* this groove connects port *e* with port *h*, view (*c*), and thus establishes a connection between the equalizing reservoir and the atmosphere; *w*, in view (*d*), is a bridge separating port *a* from cavity *c*.

The *direct-application-and-supply* port *l* leads to the train pipe through the passage *l′*, as shown in view (*a*), the train pipe being connected at *Y*. The *direct-application-and-exhaust* port *k*, view (*c*), leads direct to the atmosphere.

The *preliminary-exhaust* port *h* leads down and out to the atmosphere, as shown in view (*b*). A bushing with a $\frac{5}{64}$-inch hole through it is put in port *h* to limit the rate of discharge from chamber *D*. In this view, also, is seen how the preliminary-exhaust port *e* leads through the rotary-valve seat into chamber *D*, *the cavity or space above the equalizing piston 17*, which is connected directly with the equalizing reservoir through port *s* and the pipe connection *T*. The small groove connecting with port *e* is of such a length as will keep port *j* of the rotary valve in communication with port *e* (as the brake-valve handle is moved from release to running position) as long as there is communication between the main reservoir and the train pipe by way of port *a*, cavity *b* in rotary-valve seat, cavity *c* in rotary valve and port *l*; thereby maintaining sufficient pressure in chamber *D*, during the time the brake valve is being moved to running position, to prevent the train-pipe exhaust valve *E* opening.



(a)

FIG. 14.

(b)

The supply port *b*, views (*a*) and (*c*), is simply a cavity in the rotary seat, and is only used in full-release position to establish communication between port *a* and cavity *c* of the rotary. Fig. 15 shows the rotary valve in release position, with cavity *b* establishing communication between port *a* and cavity *c*, the passage of the air from port *a* through cavity *b*, into cavity *c*, and from thence to port *l*, and the train pipe being indicated by arrows.

FIG. 15.

The **equalizing port** *g*, Fig. 14 (*c*), leads into chamber *D*. In *running* and *full-release* positions, this port serves to establish a connection between both sides of the equalizing piston *17*, that is, between chamber *D* (or equalizing-reservoir pressure) and train pipe. Pipe connection is made between *z* on the pump governor, Figs. 3 and 4, and *V* in Fig. 14 (*a*) and (*c*); the pump governor, therefore, is operated by train-pipe pressure when used with this valve.

EQUALIZING RESERVOIR.

75. The small **equalizing reservoir** or **brake-valve reservoir**, sometimes called the little drum, Fig. 1, is generally placed under the cab foot-board. A pipe leads from this small

drum to the engineer's valve, where it connects at *T*, Fig. 14, and thence through port *s* with chamber *D*. The equalizing reservoir serves to increase the capacity of chamber *D* without enlarging the engineer's valve. Were chamber *D* of small capacity, it would be impossible to make a **gradual** service application of the brakes, for the reason that a gradual reduction of pressure could not be made in chamber *D*; the least opening from this chamber would cause a great reduction of pressure and consequently would set the brakes harder than desired.

The black gauge hand is connected at *W*, and it therefore indicates chamber *D* and equalizing-reservoir pressure. The red gauge hand is connected at *R* and so indicates main-reservoir pressure, this reservoir being piped to the brake valve at *X*.

The **equalizing piston** *17* separates chamber *D* from the train-pipe pressure, chamber *D* pressure always acting to hold it down, and train-pipe pressure to force it up. As long as these two pressures remain equal, the piston remains stationary, but if the equalizing-reservoir pressure is reduced below that in the train pipe, the piston will be raised by train-pipe pressure, which will then escape to the atmosphere through port *m*, train-pipe exhaust valve *E*, and port *n n'*, views (*a*) and (*b*). As soon as the train-pipe pressure under piston *17* is reduced below that in chamber *D*, the piston is forced down by the pressure above it, and closes the train-pipe exhaust valve *E*.

It is essential that a thorough knowledge be acquired of the ports and cavities of the brake valve, and their connections in the different positions of the rotary, in order to obtain a clear conception of the various brake-valve operations.

BRAKE-VALVE POSITIONS.

76. There are five positions in which the brake valve may be used, namely: (1) *release*, (2) *running*, (3) *lap*, (4) *service*, and (5) *emergency*.

Release Position.—This position, Fig. 14 (*a*) and (*b*), is used in releasing the brakes, and in charging the equalizing reservoir, train pipe, and auxiliary reservoirs.

Running Position.—This is the position used while the brakes are off, as when running along the road. This is the position in which the valve must be carried in order to have excess pressure.

Lap Position.—In this position, the rotary valve closes and separates all the brake-valve ports. The brake-valve handle is carried on lap position between reductions in a service stop.

Service Position.—This is the one used in making a gradual application of the brakes, such as at stations, water cranes, slow-ups, and the like.

Emergency Position.—This is used when it is desired to stop a train in the shortest possible time, as in cases of imminent danger.

OPERATION OF D-8 BRAKE VALVE.

77. It must be remembered that main-reservoir pressure is always free to enter the brake valve at *X*, and, unless otherwise stated, we shall consider 70 pounds as standard train-pipe, and 90 pounds as standard main-reservoir, pressure.

78. Release Position.—To release brakes, the brake-valve handle is placed in full-release position, namely, that shown in Fig. 14 (*a*) and (*b*). This brings the supply port *a* of the rotary valve *13* in such a position over cavity *b* in its seat that the partition *w* between port *a* and cavity *c* of the rotary is directly over the center of cavity *b* in the seat (see Fig. 15). The supply port *a* is thus directly connected with cavity *c* by means of cavity *b*, and air passes from port *a* into cavity *c*, as shown by the arrows in Fig. 15, cavity *c* being then in direct connection with port *l*. A direct connection is thus had with the main-reservoir pressure (which is always on top of the rotary valve) by way of the supply port *a* down into cavity *b* of the rotary seat, up into cavity *c* of the rotary, and then down through the direct-application-and-supply port *l* and the passage *l'*, Fig. 14, into the train pipe at *Y*, raising the pressure in the train pipe and charging the auxiliaries through the triples. At the same time that air is passing through

cavity *c* into the train pipe, it also passes into chamber *D* through port *g*, which port is exposed to cavity *c*, and in this way the pressures are kept equal both above and below the equalizing piston *17*.

In full-release position, port *j* is directly over port *e* leading to chamber *D*, and this furnishes another port connection between the main reservoir and this chamber, views (*b*) and (*d*). Thus, when the rotary is in full release, it is seen that there are two small port connections between the main reservoir and chamber *D*, and one large one between the main reservoir and train pipe.

The pump is stopped by the governor when the train-pipe pressure has reached 70 pounds, so that if the rotary is left in full-release position, 70 pounds is all that will be obtained in the main reservoir, train pipe, and equalizing reservoir, since a direct connection is established between these three places in this position.

The brake-valve handle, therefore, should be moved to running position just before 70 pounds has been reached, in order to have the proper excess pressure.

79. Running Position.—In this position, the partition *w* in the rotary valve has been moved around so as to break the connection between port *a* and cavity *c*. Air may now pass from port *a* into cavity *b*, but cannot get out. In this position, port *j* of the rotary is directly over the feed-port *f*, and port *e* is blanked. With the brake valve in this position, the main-reservoir pressure reaches the train pipe by passing down through port *j* of the rotary into port *f* and passage *f'*, and so on into chamber *r*, where it moves the excess-pressure valve *21* from its seat and passes on through passage *xf''* into port *l* leading to the train pipe. Cavity *c* still establishes communication between port *l* and equalizing port *g*, so that, as air enters the train pipe, it is also free to pass up into cavity *c* of the rotary and down through port *g* into chamber *D*. A direct connection is thus obtained in running position between the train pipe and chamber *D*, the pressures above and below the equalizing piston *17* are equal, and the black gauge hand,

which usually indicates chamber *D* pressure only, now shows train-pipe pressure also, due to the above direct connection.

In running position, air can only pass from the main reservoir by the **excess-pressure valve** *21* into the train pipe when there is 20 pounds more pressure in the main reservoir than there is in the train pipe. This is because the excess-pressure spring *20*, which holds the excess-pressure valve *21* to its seat, has a resistance equivalent to this excess of 20 pounds, which resistance must be overcome before valve *21* can be moved from its seat. If the pump is started with the brake valve in running position, the red gauge hand will show 20 pounds pressure before the black hand moves at all. The hands will continue to rise 20 pounds apart until 90 pounds is obtained in the main reservoir, and 70 in the train pipe, when the pump will stop, since the governor is operated by train-pipe pressure and is adjusted to 70 pounds. The difference between the main-reservoir and train-pipe pressures is called the **excess pressure.**

80. Lap Position.—With the valve handle in this position, all ports are closed. Port *j* of the rotary, views (*b*) and (*d*), has been moved around past port *f*, and the rotary now covers port *g*. The main reservoir, chamber *D*, and train pipe are entirely separated from one another, and the black hand now indicates only chamber *D* or equalizing-reservoir pressure, as there is now no port connection between the upper and lower sides of the equalizing piston *17*.

81. Service Position.—When in this position, the valve handle will have been moved so that groove *p* of the rotary *13*, view (*d*), connects the preliminary-exhaust port *e*, views (*b*) and (*c*), with port *h* leading to the atmosphere. The engineer leaves the rotary in service position until the black hand shows that the desired reduction of chamber *D* pressure above piston *17* has been made, when the rotary is again moved to lap position. In service position, the only port connection through the rotary is between chamber *D* and the atmosphere, through ports *e*, *p*, and *h*. Chamber *D* pressure, on top of the

equalizing piston *17*, now being reduced below train-pipe pressure underneath it, the piston is raised, opening the train-pipe exhaust port *E* and permitting train-pipe air to escape through ports *m* and *n n'* to the atmosphere at the train-pipe exhaust *25*. Train-pipe air continues to escape at the train-pipe exhaust until the pressure below piston *17* is a trifle less than that in chamber *D* above it, at which time the piston is forced down, closing the train-pipe exhaust valve *E*. If the rotary is again placed in service position, the events just described will again occur, the amount of train-pipe reduction corresponding to the reduction of equalizing-reservoir pressure. When the engineer makes a service application of the brakes, he simply makes a reduction of chamber *D* pressure, and then piston *17* automatically reduces the train-pipe pressure; while piston *17* is reducing the train-pipe pressure, the triple-valve pistons are automatically reducing the pressure in the auxiliaries by allowing it to escape into the brake cylinders.

82. Emergency Position.—In this position the cavity *c* of the rotary valve is so placed that it connects the direct-application-and-supply port *l*, which leads to the train pipe, with the direct-application-and-exhaust port *k* leading to the atmosphere. This port *k*, the cavity *c*, and the port *l*, all being large, cause a large opening to be made between the train pipe and atmosphere, and, consequently, a sudden heavy train-pipe reduction is the result. This sudden reduction causes the triples near the engine to assume emergency position. It was seen in the study of the quick-action triple that when one quick-action triple went into emergency position, a sudden reduction of train-pipe pressure near it was made through the quick-action part of the triple; this started the next one, and so on to the end of the train, each triple helping to keep this sudden reduction traveling quickly backwards throughout the train. In the service application of the brake, all train-pipe reductions escape to the atmosphere through the train-pipe exhaust, while in emergency, a sudden reduction is made to start the first quick-action triples into emergency, and these triples make sudden reductions of train-pipe pressure; but,

T

(a)

(b)

Fig. 16.

instead of wasting the air by passing it to the atmosphere, they put it into the brake cylinders, where it is used to increase the braking power.

ENGINEER'S D-5, E-6, OR F-6 BRAKE VALVE.

83. The **F-6 brake valve** is illustrated in Fig. 16, wherein (*a*) and (*b*) are cross-sectional views, while (*c*) is a plan view with the top part of the valve body and the rotary valve *13* removed, so as to show the ports and cavities in the rotary-valve seat *3*. In (*d*) is shown a plan view of the under side, or face, of the rotary *13*, showing the ports and cavities in it. View (*e*) represents a section of the valve taken through the passage *f′ f″* to show the passages to and from the feed-valve attachment.

Comparing Figs. 16 (*c*) and 14 (*c*), it will be seen that both the form and location of ports *l* and *k* and cavity *b* are practically the same; port *f* is in about the same location, but in the D-8 valve it is $\frac{1}{4}$ inch in diameter, whereas in the F-6 valve it is $\frac{9}{32}$ inch; port *h* of the D-8 valve is replaced in the F-6 valve by the groove *h* that leads into the exhaust port *k*; the preliminary-exhaust port *e* is located as in the D-8 valve, and the bushing for limiting the discharge of air from chamber *D* is placed in this port. [See Fig. 16 (*b*).] Port *g* in the F-6 valve is $\frac{1}{4}$ inch in diameter and is placed nearer to port *b*, and is in such a position that it will not register with port *j* of the rotary valve when the brake valve is being moved to emergency position. Port *g* in the D-8 valve is only $\frac{3}{16}$ inch in diameter.

Comparing Fig. 16 (*d*) with the plan of the D-8 rotary valve shown in Fig. 14 (*d*), it will be seen that cavity *c* is in about the same position in each case, but that the two differ slightly in form. The projection in cavity *c* of the F-6 brake valve being for the purpose of covering port *g* in lap position of the brake valve. The bridge *w* is made wider in this valve to reduce the wear at that point. Port *j* is made round, whereas in the D-8 valve it is lengthened so as to connect main-reservoir pressure with feed-port *f* before the bridge *w* cuts off

communication between the supply port *a* and cavity *c* as the brake valve is being moved to running position. Also, the groove *p* is lengthened in the F-6 valve so as to keep the preliminary exhaust port *e* in communication with groove *h* and exhaust port *k* in all positions of the brake valve between service and emergency positions. This causes chamber *D* to be emptied of all pressure in emergency application.

84. The excess-pressure valve *21* of the D-8 valve is replaced in the F-6 valve by the feed-valve attachment *33*, (*b*) and (*c*). The excess-pressure valve in the D-8 maintains a predetermined difference of pressure between the main reservoir and the train pipe; the feed-valve attachment can be regulated to give any desired train-pipe pressure (as high as that in the main reservoir if desired) regardless of what the main-reservoir pressure is. The pump governor used with the F-6 valve controls the pump and determines the excess pressure.

The air connection *z* of the pump governor (Figs. 3 and 4) is connected by a pipe at *R*, Fig. 16, and the governor therefore is operated by main-reservoir pressure.

The equalizing reservoir is connected at *T*, the black gauge hand at *W*, and the red one at *R*. The pipe connections to the train pipe and the main reservoir are the same in this as in the D-8 valve. The various operating positions of the brake-valve handle (*release*, *running*, *lap*, *service*, and *emergency*) are also the same as for the D-8 valve, as shown in Fig. 14 (*c*).

OPERATION OF F-6 BRAKE VALVE.

85. The **feed-valve attachment,** shown in Fig. 16 (*b*), consists of a spring box *69*, within which is contained a regulating spring *68* which exerts an upward pressure on the feed-valve piston *74* above it, and within the feed-valve body is a supply valve *63*, the lower stem of which is of such a length that it rests on the upper stem of the feed-valve piston. When this piston is up in its normal position it holds the valve *63* from its seat against the resistance of the spring *64*, which tends to hold the valve down. When the brake valve is in

running position, chamber *u*, above the supply valve *63*, is in connection with main-reservoir pressure through the passage *f″f′*, port *f* in the rotary seat, and port *j* in the rotary valve. Chamber *B*, just above piston *74*, is in direct communication with the train pipe at all times through port and passage *i* and direct-application-and-supply port *l*, view (*e*). Chamber *B* is therefore always filled with train-pipe pressure, which exerts a downward pressure on piston *74*, while chamber *u* is always filled with main-reservoir pressure. The downward pressure of the air in chamber *B* on piston *74* is resisted by the spring *68*, which is adjusted to resist a downward pressure of 70 pounds per square inch. Just so long as the train-pipe pressure in chamber *B* is less than 70 pounds, the spring *68* will hold piston *74* up sufficiently to keep the supply valve *63* unseated, and main-reservoir pressure will flow by valve *63* into chamber *B* and on into the train pipe, view (*e*). When the pressure in the train pipe and in chamber *B* reaches 70 pounds, the piston *74* is forced down, compressing the spring *68*. As piston *74* descends, the supply valve *63* is forced to its seat by the spring *64*, and no more air can pass from the main reservoir into the train pipe through the feed-valve attachment (or **train-pipe governor**, as it is sometimes called,) until a reduction of train-pipe pressure has occurred.

If leaks reduce the train-pipe pressure below 70 pounds, the spring *68* raises piston *74* and supply valve *63*, and allows main-reservoir pressure to restore the loss due to leakage, after which the supply valve *63* is again closed. The tension of the spring *68* is regulated by means of the regulating nut and screw *70*. Screwing up increases the tension of spring, and, consequently, the train-pipe pressure, and unscrewing reduces train-pipe pressure. In view (*b*) the feed-valve attachment is shown in section; a small portion of the body is further broken away so as to show the port *i* by which the air, after passing from *u* through the feed-valve into *B*, makes its way along the passage shown into port *l*; this passage runs along behind the passage *f″f′*, exactly on the same level with it, so that it cannot be seen in view (*b*); its position, however, is shown in view (*e*).

86. Release Position.—When the brake valve is in this position, (*a*) and (*b*), the supply port *a* of the rotary stands directly over cavity *b* of the rotary seat, and port *j* of the rotary stands directly over the preliminary-exhaust port *e*, view (*b*). Main-reservoir pressure is free to pass into port *a* of the rotary, and down into cavity *b* of the rotary seat. The bridge *w* between cavity *c* and port *a* of the rotary, view (*d*), now stands across the middle of cavity *b*, so that the air entering cavity *b* from port *a* passes under this bridge and up into cavity *c*, as shown in Fig. 15. The air passes from cavity *c* into the supply port *l* and out into the train pipe at *Y*. Train-pipe pressure increasing, the triple pistons are forced to release position and the auxiliaries are charged. While the air is passing through cavity *c* to port *l*, it is free to pass down through the equalizing port *g* into chamber *D*, and thence out to the equalizing reservoir through port *s*. During the time air is feeding into the chamber *D* through port *g*, main-reservoir air is feeding through port *j* of the rotary and the preliminary-exhaust port *e* of its seat into the chamber *D*. In release position, one large port leads from the main reservoir to the train pipe, and two small ports lead to the equalizing reservoir (through chamber *D*). In view (*d*) is seen a very small port *r*, called the engineer's **warning port,** drilled through the rotary valve in such a position that, when the latter is in full release, this warning port is directly over the exhaust port *k* in the rotary seat, view (*c*). Main-reservoir air on top of the rotary blows through this small warning port into the exhaust port *k*, and the sound of escaping air is heard by the engineer. This sound is to warn him that he must not leave his valve in full-release position too long, for the following reasons: With this valve the pump is not stopped until 90 pounds pressure is obtained in the main reservoir, as main-reservoir pressure operates the pump governor, which is adjusted to 90 pounds. Now, there is a direct connection between the main reservoir and train pipe in full-release position, and if the rotary is left there, 90 pounds pressure will be obtained in both the main reservoir and train pipe. This high pressure, getting into the auxiliaries, would be likely to slide wheels when the brakes were applied, and there would

also be a lack of excess pressure for releasing brakes. Besides this, if the valve were now placed in running position, the feed-valve attachment would be held closed until train-pipe pressure was reduced to 70 pounds, and, consequently, train-pipe leaks would tend to cause the brakes to "creep on" until both train-pipe and auxiliary pressures were reduced to 70 pounds, when the feed-valve would begin operating again and supply the air lost through these leaks.

87. Running Position.—In this position, port *j* of the rotary is in communication with port *f* of the rotary seat, and air from the main reservoir passes down through ports *j*, *f*, through the passage *f′ f″*, and on through the feed-valve attachment and into the train pipe by way of passage *i* and port *l*, as explained in the description of the feed-valve attachment. The air continues to flow thus until the train-pipe pressure reaches 70 pounds, when the feed-valve attachment closes. As air passes through the feed-valve attachment through port *i* and on into port *l* and the train pipe, some of it passes up into cavity *c* in the rotary and down through port *g* into chamber *D*. A connection is thus obtained between the train pipe and chamber *D*, that is, between both sides of the equalizing piston *17*. The black gauge hand is piped to the equalizing-reservoir connection at *T*, and, as there is in running position a port connection between the train pipe and chamber *D* through the cavity *c* in the rotary and port *g*, the black hand must in this position indicate both chamber *D* and train-pipe pressures. The same movement that changes the rotary *13* from full release to running position, closes the warning port *r* and moves the bridge *w* of the rotary so that it prevents the passage of air from cavity *b* of the rotary seat into cavity *c* of the rotary. The feed-valve attachment keeps the train-pipe pressure at 70 pounds, and the pump governor stops the pump when main-reservoir pressure has reached 90 pounds, so that, when everything is fully charged and the valve is in running position, the black hand should register 70 pounds and the red hand 90.

88. Lap Position.—In this position, the rotary has been moved around so as to close all connections. Port *j* is closed to port *f*; the equalizing port *g* is covered so that it is shut off from cavity *c*; and connection between the top and bottom of the equalizing piston *17* is cut off.

89. Service Position.—In this position, the rotary has been moved so that groove *p* in the face of the rotary valve, view (*d*), connects the preliminary-exhaust port *e* in the rotary seat with the port *h*, which leads into the direct-application-and-exhaust port *k*. A direct connection is thus established between chamber *D* and the atmosphere, and air from chamber *D* can pass through port *e*, groove *p*, and ports *h* and *k* to the atmosphere. The reduction of the pressure in chamber *D* causes the equalizing piston to rise and open the train-pipe exhaust valve *E*, as already described in the operation of the D-8 valve.

90. Emergency Position.—In this position the rotary has been moved around so that cavity *c* connects port *l* (leading to the train pipe) with the exhaust port *k* (leading to the atmosphere). The opening of these large ports causes a sudden train-pipe reduction, which gives an emergency application of the brakes, as already described in the case of the D-8 valve.

SLIDE-VALVE FEED-VALVE.

91. Introductory.—All engineer's brake valves prior to the 1892 brake valve, were provided with an excess-pressure valve, the duty of which was to maintain a fixed difference of pressure between the train pipe and main reservoir when the brake valve was in running position. While the excess-pressure valve performed that duty, yet several faults were to be found with it, which finally led to its being abandoned for the feed-valve attachment. The strength of the spring in the excess-pressure valve fixes the amount of excess pressure carried, and this amount could not be changed without adding washers to increase the tension of the spring, or substituting a spring of different strength. Moreover, it did not regulate the amount of

pressure carried in the train pipe, but simply maintained a fixed difference in pressure between the train pipe and main reservoir; hence, if the main reservoir were overcharged (as could happen when the brakes were held on for some time), the train pipe also became overcharged when the brake valve was moved to running position. Again, if the main reservoir equalized with the train pipe when the brakes were being released, and the brake valve was then moved to running position, the brake valve would practically be lapped until 20 pounds excess pressure was obtained, during which time the brakes were very apt to creep on. If the main reservoir equalized with the train pipe at a pressure greater than 70 pounds, the governor would not start the pump until the train-pipe leaks reduced train-pipe pressure below 70 pounds, and the 20 pounds excess had then to be pumped. It was due to these faults of the excess-pressure valve that the feed-valve attachment was introduced with the 1892 brake valve.

92. The feed-valve attachment is simply a form of pressure-reducing valve, and its duty is to regulate the train-pipe pressure to a standard pressure—usually 70 pounds—just as the signal-reducing valve regulates the signal-pipe pressure to 40 pounds. The feed-valve attachment overcame all the objectionable features of the excess-pressure valve and proved very successful on trains of short and medium length. However, when used with long freight trains it developed a serious fault that finally led to the adoption of the **slide-valve feed-valve,** brought out with the G-6 brake valve in 1900.

The feed-valve attachment is operated by train-pipe pressure acting on a diaphragm against the force of a regulating spring. It was found that this spring begins to be compressed when the train-pipe pressure reaches about 45 pounds, and that as the pressure is increased above that amount the spring is compressed more and more until at 70 pounds it is compressed sufficiently to permit the feed-valve to close and cut off communication between the train pipe and the main reservoir. On account of this action, the feed-valve begins to close gradually from the time train-pipe pressure reaches 45 pounds or

thereabouts, thus gradually reducing the flow of main-reservoir air into the train pipe. The result is that on a long train where the feed-valve is adjusted for 70 pounds and there is considerable train-pipe leakage, train-pipe pressure cannot be raised to 70 pounds with the brake valve in running position. By the time train-pipe pressure reaches, say, 65 pounds or thereabouts, the feed-valve has closed to such an extent that just sufficient air can pass it to make up for the loss through train-pipe leakage; consequently, it is impossible to increase the pressure in the train pipe above that amount. This defect has been overcome in the slide-valve feed-valve, which will now be described and explained. No modification is necessary in existing brake valves in order to use the slide-valve feed-valve, as the method of attachment is exactly the same as that of the feed-valve attachment of the 1892 brake valve.

93. External Construction.—A very good idea of the external construction of the slide-valve feed-valve can be obtained from Figs. 17 and 18, the first of which is a view from the front, while the second is a view from the rear. As its name implies, the slide-valve feed-valve really consists of two parts *X* and *Y*, Fig. 17. Part *X* contains the slide-valve arrangement, and really governs the train-pipe supply, while the feed-valve arrangement in part *Y* [which is practically the same in construction (see Fig. 16) and identically the same in operation as the feed-valve attachment of the 1892 brake valve], is used to operate the slide-valve part *X*. It is due to the adoption of a slide valve instead of a poppet valve for regulating the supply of air to the train pipe that a wide open communication between main reservoir and train pipe is maintained until the standard pressure is obtained. Since the starting friction of the slide-valve is greater than the sliding friction, it follows that once the slide-valve is started it will move its full stroke and so totally open or totally close the supply port; hence, there can be no gradual closing of the supply port as in the old feed-valve attachment.

94. Passages a, f, and i.—Fig. 19 shows a back view of the slide-valve feed-valve with part of the valve so broken away

FIG. 17.

2309

FIG. 18. 2367

FIG. 19.

FIG. 20. 2367

as to show the passages *a*, *f*, and *i*, and their relations to ports *b* and *l*. When the feed-valve is in position on the brake valve, the passage *f* connects with the passage *f'* in the brake valve, Fig. 16, so that it is charged with air at main-reservoir pressure when the brake valve is in running position. Since port *l* in the supply-valve bushing connects passage *f* with chamber *F*—the space surrounding the supply valve *55*—it follows that chamber *F* is charged with main-reservoir pressure whenever passage *f* is so charged.

Passage *i* in the feed-valve connects with passage *i* in the brake valve, Fig. 16; hence it is always in direct communication with the train pipe and charged with train-pipe air. Furthermore, passage *i* is connected with chamber *F* through the supply port *b* in the supply-valve bushing. Passage *a* connects passage *i* with chamber *A*—the space between the diaphragm *57* and the regulating valve *59*—hence, chamber *A* is always charged with train-pipe air, since it is in direct communication with it.

The arrows indicate the flow of air through the feed-valve when it is open and supplying air to the train pipe. It will be observed that a portion of the feed-valve has been broken away in such a manner as to show the regulating valve *59*; also, it shows how the end of the passage *c* opens into chamber *B*—the space surrounding the regulating valve.

95. Passage c.—Fig. 20 is a perspective view of the feed-valve with the cap nut *53* removed and part of the valve broken away to show the course of the passage *c* and its relation to the regulating valve *59* and to passage *a*. Passage *c* connects chamber *B* with chamber *E*—the space between the supply-valve piston *54* and the cap nut *53*—thus maintaining equal pressures in the two chambers. The regulating valve *59* controls communication between chambers *A* and *B*, so that when it is open chamber *E* is in direct communication with the train pipe through the passage *c*, chamber *B*, valve *59*, chamber *A*, and passages *a* and *i*. A portion of the feed-valve in Fig. 20 is broken away so as to show how the end of passage *a* opens into chamber *A*.

96. Slide-Valve Arrangement.—Fig. 21 is a side view of the feed-valve attachment, with the upper part *X* sectioned through the center to show the arrangement of the supply valve *55*, and the lower part *Y* below the line *A B* sectioned in such a way as to show the passages *a* and *c* and chamber *B*. A portion of the upper part *X* of the valve is broken away to show the end of the passage *i*.

The supply valve *55* controls port *b* leading from chamber *F* into the passage *i*. This slide valve is operated by means of the supply-valve piston *54* and the supply-valve-piston spring *58*. Although piston *54* makes a snug fit in its bushing it is not provided with a packing ring for the reason that a certain amount of leakage from chamber *F* into chamber *E* is necessary in order that the feed-valve may work properly. The spring *58* is made sufficiently strong to force piston *54* and supply valve *55* back against the flush nut *52* (which acts as a stop for the piston) whenever the pressures in chambers *F* and *E* become equal. Port *b*, therefore, is closed when the pressure in chamber *E* equals that in chamber *F*. When the pressure in chamber *E* is less than that in chamber *F*, the greater pressure on the chamber *F* face of piston *54* forces the piston forwards, moving valve *55* with it, and thus opening port *b*. Therefore, port *b* is always open when the pressure in chamber *E* is less than that in chamber *F*. The supply-valve spring *56* is intended to hold supply valve *55* on its seat when that valve is relieved of pressure, in order to prevent dirt from getting between the valve and its seat.

In Fig. 21, chamber *B* is shown with the regulating valve *59* removed.

97. Feed-Valve Arrangement.—As already remarked, the feed-valve, part *Y* of this valve, is practically the same in construction as the old feed-valve attachment. This will be more readily seen by comparing part *Y* of Fig. 20 with the feed-valve in Fig. 16 (*b*). Passage *c* of Fig. 20 corresponds to passage *f''* of Fig. 16, and the passage *a* to passage *i*. The operation of the feed-valves is identically the same. The vent hole *x*

Fig. 21

FIG. 22.

is to prevent pressure (due to leakage past the diaphragm *57*) accumulating in the spring box and thus rendering the feed-valve inoperative.

98. Operation of Slide-Valve Feed-Valve.—On account of the parts *X* and *Y* being at right angles to each other, it is difficult to illustrate the operation of the valve by means of true sectional views. For that reason, two conventional views, Figs. 22 and 23, have been prepared for use in explaining the operation of the slide-valve feed-valve.

At such times as the feed-valve is not under pressure, port *b* is closed while the regulating valve *59* is open. The spring *58* forces the supply valve *55* back until it covers port *b* (as in Fig. 23), while the regulating spring *67* forces the diaphragm to unseat the regulating valve *59* (as in Fig. 22).

Fig. 22 shows the position of the parts of the feed-valve when the train pipe is charged to less than 70 pounds and air is feeding through the feed-valve into it. Under those conditions, main-reservoir air enters passage *f* and chamber *F*, forcing piston *54* forward until it uncovers port *b*. The air then flows from chamber *F* through port *b* into passage *i* and thence into the train pipe, increasing the pressure there.

While train-pipe pressure is less than 70 pounds, the regulating valve *59* is held off its seat by the regulating spring *67* and there is direct communication between chamber *E* and the train pipe through passage *c*, valve *59*, and passages *a* and *i*. The leakage that takes place past the piston *54* therefore, passes directly to the train pipe as indicated by the arrows, so that chambers *E* and *A* are maintained at train-pipe pressure. When 70 pounds is obtained in the train pipe, the pressure on the diaphragm *57* is sufficient to compress the regulating spring *67* enough to allow the regulating valve *59* to close. This cuts off communication between chamber *E* and the train pipe, and the leakage occurring past piston *54* then quickly charges chamber *E* to the same pressure as chamber *F*, which allows the spring *67* to move the supply valve *55* to "closed" position, as shown in Fig. 23. In this position no air can feed into the train pipe, since port *b* is closed.

The parts of the feed-valve remain in the positions shown as long as the train-pipe pressure remains at 70 pounds. Any reduction of train-pipe pressure, however, allows the spring *67* to expand and unseat the regulating valve *59*; pressure in chamber *E* is then immediately reduced to train-pipe pressure, so that the greater pressure of the air in chamber *F* forces the piston *54* to "open" position, as shown in Fig. 22.

99. Regulation.—If the slide-valve feed-valve does not regulate train-pipe pressure to the proper amount, it can be made to do so by adjusting the regulating nut *65*.

If it maintains a pressure below the standard, turn the regulating nut *65* slowly until the tension of the spring *67* is sufficiently increased to give proper regulation.

If it maintains too high a pressure, place the brake valve in service position and reduce the train-pipe pressure several pounds below standard; then turn the regulating nut *65* so as to relieve the spring *67* of a little of its tension, place the brake valve in running position, and note the pressure that is then maintained. If still too high, proceed again as above, and continue to so regulate until the feed-valve is properly adjusted.

100. Care.—In order that the feed-valve may perform its functions properly, it is necessary that it be cleaned and oiled occasionally. If the feed-valve is to be cleaned when the air-brake system is charged with air, it must be relieved of all pressure before it can be taken apart. To do this, close the cut-out cock in the train pipe underneath the brake valve, so as to save the air in the train pipe, and place the brake valve in service or emergency position to empty the feed-valve and the short piece of train pipe above the cut-out cock; the feed valve may then be taken apart and cleaned. Clean both the piston *54* and its cylinder, and the slide valve *55* and its bushing, very carefully, leaving no lint on the parts, for it will cause trouble; clean, also, the regulating valve and its seat and the hole in the cap nut *61* into which the valve *59* extends.

In oiling the supply valve *55*, only a small amount of valve oil, vaseline, mutton tallow, or some similar lubricant should be used, the oil being applied with the finger. Only a very

FIG. 23.

small amount of some light lubricating oil (engine oil will do) should be used on the supply-valve piston *54* and its cylinder, and that should be well rubbed on with the fingers. If too much or too heavy oil is used on these parts, it will get into the grooves of the piston and act as an oil packing that will interfere very materially with the action of the feed-valve. The regulating valve *59* should not be oiled, but should be replaced dry.

101. Defects.—Like any other piece of mechanism, the slide-valve feed-valve is liable to develop defects, which, while they may not be common to it, yet may occur occasionally; hence, it is well to understand the effects of possible defects on the operation of the feed-valve. The possible defects are: (1), leaks past the cap nut *53* or *61*; (2) leaky supply valve *55*; (3) leaky regulating valve *59*; (4) piston *54* too loose a fit; (5) piston *54* too tight a fit; (6) spring *58* broken; (7) regulating valve *59* gummed up; (8) ruptured diaphragm *57*.

1. *Leaky Cap Nuts 53 or 61.*—Leakage past either cap nut will produce the same effect. As long as the leakage is less than the leakage past the piston *54* into chamber *E*, it will simply increase the interval of time between the closing of the regulating valve *59* and the closing of port *b* by the slide valve *55*; the train pipe may thereby be somewhat overcharged each time the feed-valve acts.

If the leakage is greater than that occurring past piston *54*, the pressure in chamber *E*, instead of being increased to chamber *F* pressure when the regulating valve *59* closes, will be reduced still farther; the supply valve *55*, therefore, will remain open all the time, and the feed-valve will be inoperative. To overcome this defect temporarily, use a rubber washer if at hand, or, if not, one of leather or pasteboard or some similar substance.

2. *Leaky Supply Valve 55.*—A leaky supply valve *55* will allow main-reservoir air to leak into the train pipe after the supply valve has covered port *b*. If this leakage is greater than the train-pipe leakage, train-pipe pressure will be increased above standard pressure.

3. *Leaky Regulating Valve 59.*—A leak past this valve may be due either to a defect in the valve or its seat, or to dirt

between the valve and its seat. If the leakage is less than that occurring past the piston *54*, no especial harm will result, since the pressure in chamber *E* will be maintained. If, however, the leakage is greater than that past piston *54*, chamber *E* pressure will be reduced thereby and maintained about equal to train-pipe pressure, and the supply valve *55* will be held open by chamber *F* pressure. The feed-valve, therefore, will be inoperative, and train-pipe and main-reservoir pressures will equalize. If the trouble is due to dirt, cleaning will overcome it; otherwise, the valve must be reseated.

To test for a leaky supply valve 55, or regulating valve 59, proceed as follows: Close the cut-out cock under the brake valve so as to save train-pipe air; then place the brake-valve handle in emergency position to empty the short piece of train pipe above the cut-out cock and relieve the feed-valve of all pressure. Next remove the spring box *62*, together with the regulating spring *67*, the diaphragm spindle, and diaphragm, so that you can get at the chamber *A* end of the regulating valve *59* and have free access to the end of port *a* opening into chamber *A*. Then move the brake-valve handle to running position. There will be a severe blow from port *a* for a second or two, and then, if everything is in good condition, the blow will stop and not occur again.

To test the supply valve, first test for a leaky regulating valve *59* by holding a wet finger or a lighted match before it and noting by the coolness of the finger or by the action of the flame whether any air is escaping past the valve. If the regulating valve is tight, there should be no blow from port *a* (assuming the cap nut *53* and *61* to be tight), and any leakage from port *a* will indicate a leaky supply valve. A leaky supply valve will cause a continuous blow from port *a*.

4. *Piston 54 Too Loose a Fit.*—If the fit of the supply-valve piston *54* should be made so loose that the leakage past it is more than the regulating valve *59* could accommodate, the pressure in chamber *E* would remain equal to that in chamber *F* and the supply valve *55*, consequently, would remain closed after the regulating valve *59* had opened. This would make the slide-valve feed-valve inoperative, since the only way air

could get through the slide-valve feed-valve into the train pipe would be past the regulating valve *59*.

5. *Piston 54 too Tight a Fit.*--If this piston is fitted too tightly, or if it becomes too tight fitting through grease, oil, or gum, the proper leakage past the piston will be interfered with and the interval between the closing of valve *59* and valve *55* will be increased, thereby tending to overcharge the train pipe.

The piston is made slightly less in diameter than its cylinder, and it is provided with two grooves that are intended to prevent undue leakage. If too much oil is used in the feed-valve, it will collect in these grooves and form an oil packing that may so limit the leakage past the piston as to very seriously interfere with the proper working of the feed-valve, and the train pipe may become overcharged every time the regulating valve closes.

6. *Spring 58 Broken.*—If spring *58* is broken or too weak to force piston *54* and slide-valve *55* back to closed position, the feed-valve will be inoperative. The port *b* will remain uncovered, and main-reservoir pressure will equalize with the train pipe. If this spring is too weak, the difficulty may be temporarily overcome by stretching the spring or using washers between it and the cap nut.

7. *Regulating Valve 59 Gummed Up.*—If the regulating valve is so gummed up that air from chamber *E* cannot escape past it as quickly as air from chamber *F* leaks into chamber *E*, supply valve *55* will be periodically closed and opened as long as regulating valve *59* is open. If valve *59* should become entirely closed, the pressure in chambers *E* and *F* would soon equalize and the valve *55* would move to closed position and remain there, thus rendering the feed-valve inoperative. Cleaning, of course, would overcome this difficulty.

THE AIR BRAKE.

(PART 2.)

DEFECTS AND THEIR REMEDIES.

THE PUMP GOVERNOR.

1. Its Importance.—The air pump is the life of the air-brake system, since its duty is to supply air, without which the brakes cannot be operated. Anything that renders the pump inoperative, therefore, makes the air-brake system useless.

The pump governor is a throttle valve whose duty is to automatically control the air pump; hence, any disorder in the governor will affect the working of the pump and make the brake system less reliable and effective, or it may render the system entirely useless until cut out.

IMPROVED GOVERNOR.

2. Causes of Failure to Operate.—If the governor does not operate the pump properly, and cannot be made to do so by adjusting the tension of the spring *41*, the trouble may be due to any of the following causes: (1) Leaky pin valve; (2) steam valve held open by solid matter on its seat; (3) relief port stopped up; (4) drip pipe frozen or stopped up; (5) pin valve held on its seat by the spring box; and (6) governor piston stuck in bushing.

1. *Leaky Pin Valve.*—This may be due to the pin valve *b*, Fig. 3,* not seating properly; or to solid matter, such as dirt,

* All figure numbers used in this Section refer to the illustrations in *The Air Brake*, Part 1.

gum, or scale, holding the valve from its seat. A leaky pin valve allows air at main-reservoir pressure (or train-pipe, as the case may be) to pass from chamber *a* past valve *b* and through passage *d* into chamber *e* above the governor piston *28*. If the air leaks past the valve faster than it can escape through the relief port *c*, pressure will accumulate in chamber *e* and force the governor piston downwards, so as to wholly or partially close the steam valve *26*. If the steam valve is closed, the pump will, of course, stop; if only partially closed, the steam supply will be throttled and the pump will work more slowly than usual. A slight leak past the pin valve will simply make the governor less prompt in starting the pump after the pin valve closes, and it will be indicated by a constant discharge of air from the relief port *c*.

The pin valve may be removed for cleaning by unscrewing the spring box from the diaphragm body.

2. *Steam Valve Held Open.*—If the steam valve *26* is held from its seat by dirt or solid matter, the pump will continue to work until sufficient pressure is accumulated in the main reservoir to stop it. In this case, although the pin valve *b* may work properly, and open when a main-reservoir pressure of 90 pounds is obtained, yet the dirt on the seat of the steam valve will prevent the steam valve from closing, and the pump, consequently, will continue to work, although at a slower speed than usual. A *leaky steam valve*, also, will keep the pump moving slowly.

3. *Relief Port Stopped Up.*—It will be remembered that the duty of the relief port *c* is to allow the air to escape from chamber *e* when the pin valve *b* closes, so that the pump will start promptly. If port *c* is stopped up, this means of escape is cut off, and the air will have to leak past the packing ring *29* and out of the drip pipe. The rapidity with which it will do this depends on the fit of the packing ring; if this fit is at all snug, the governor steam valve *26* may not open until some little time after the pin valve closes. In this case, therefore, it is possible for leaks to reduce main-reservoir pressure several pounds before the pump begins to work again.

4. *Drip Pipe Stopped Up.*—If the drip pipe is frozen or stopped up and the stem of the steam valve *26* is worn, steam will feed up into the chamber under the governor piston and prevent the piston from being forced downwards to close the steam valve *26*. The pump, therefore, will continue to work until sufficient pressure is accumulated to stop it. A worn steam-valve stem will be indicated by steam escaping from the drip pipe—if the latter is not stopped up. Even though the stem does not leak sufficiently to prevent the steam valve from being closed, the pump will continue to work, for air will leak down past the piston packing-ring as soon as the pin valve opens, and accumulate under the piston. This soon raises the piston, and thus opens the steam valve. The pump then starts, and continues to work until stopped by the pressure in the main reservoir.

5. *Pin Valve Held on Its Seat by Spring Box.*—If the pin valve is too long, or the edge of the diaphragm body so reduced that the pin valve is held on its seat when the spring box is screwed down tight, the governor will not work at all. To test for this defect, slack off on the spring box and see if the governor will then operate.

6. *Governor Piston Stuck in Bushing.*—If the bushing in which the governor piston works becomes badly worn, the piston is liable to stick at the lower end of its stroke, and the pump will not start. A light tap on the governor or on the steam pipe near it is usually sufficient, however, to start it operating again.

OLD-STYLE GOVERNOR.

3. Defects of This Governor.—All that has been said about the causes of trouble with the improved governor is equally applicable to the old-style governor, with the exception of that part which refers to the relief port *c* of the former kind.

Besides the sources of trouble already enumerated, the old-style governor has another one: The diaphragm *19*, Fig. 4, is not sufficiently supported, and, as a consequence, train-pipe

pressure sometimes raises the diaphragm until it "buckles." When this occurs, the regulating spring *18* seems to lose all control of the diaphragm, and the pin valve *17* is liable to open and stop the pump at almost any pressure—sometimes stopping it before standard pressure is obtained, and at other times not until standard pressure has been exceeded. A governor in this condition is worse than useless, and should be cut out of service until a new diaphragm can be substituted. In fact, whenever the governor becomes disabled, and, for any reason, cannot be repaired on the road, it should be cut out of service, and the pump operated by hand—by means of the pump throttle.

CUTTING OUT A GOVERNOR.

4. In case a governor becomes disabled, it may be cut out by placing a blind gasket in the air pipe leading to it, as, for instance, in the union at *z*, or by plugging the small opening that leads into chamber *a*. In either case, pressure will be excluded from chamber *a*, and, consequently, the steam valve will remain open, thus providing for the steam a free passage through the governor.

PUMPS.

PACKING THE PUMP.

5. The **life and efficiency** of an air-brake pump depend, to a great extent, on the care it receives. In packing such a pump, any substance that will harden, such as asbestos, should not be used. Also, care should be exercised not to screw the packing gland nuts too tight, as the rubbing friction between the piston rod and packing, when the latter is pressed too hard against the former, may produce sufficient heat to burn the packing out, and cause unnecessary trouble on the road. If the gland nuts can be screwed up sufficiently by hand to prevent a blow, no wrench should be used. A blow should be stopped as soon after it occurs as possible, as the steam, in

escaping, tends to cut a channel through the packing along the piston rod, and thus spoil it.

A **swab** saturated with oil should always be used on the piston rod. This not only serves to keep the rod and packing, but also the air cylinder, in good condition, as some of its oil works down into the latter and helps to lubricate it.

OILING THE PUMP.

6. Steam Cylinder.—A sufficient quantity of good oil should be used in the steam cylinder to keep the parts well lubricated and prevent groaning. The **quantity** of oil necessary will depend on the kind of oil used, and also on the pump itself, as some pumps require more than others. If the pump groans constantly, and the pump exhaust or the drip pipes show that considerable water is working through the steam cylinder, its dry pipes should be examined for leaks that might allow water to reach the pump and wash out the oil.

7. Air Cylinder.—The **quantity** of oil to be used in the air cylinder depends to a great extent on the pump, but in any case it should be used very sparingly. The amount should only be sufficient to keep the packing rings free, and prevent the cylinder walls from cutting. If too much is used, a gummy deposit is formed in the air cylinder and air passages, and on the air valves, which tends to cause heating; also, oil works back into the brake valve and triples, and causes them to work poorly; 32° West Virginia well oil is considered best for use in the air cylinder. The oil may be fed to the cylinder by means of a swab on the piston rod, or through the air-cylinder oil cups, *but it should never be fed through the air inlets,* as it will close the air passages, gum up the valves, reduce their lift, and sooner or later result in overheating. Animal or vegetable oils should not be used in the air cylinder, as they "gum" very readily; also, mineral oils that have a low flashing point, as, for instance, kerosene, should not be used in a hot cylinder, as they generate an explosive gas that ignites at a comparatively low temperature, and may, therefore, cause trouble.

CLEANING OUT THE PUMP.

8. Occasionally, the air cylinder of an air pump gets a fit of "groaning." When this occurs, the lower air-cylinder head should be removed, the piston pushed up to the top end of the cylinder, and the cylinder thoroughly cleaned by means of a piece of waste saturated with kerosene. The cylinder should then be wiped out thoroughly with clean waste, and oiled lightly with a good grade of mineral oil or vaseline, after which the head may be replaced.

If the air passages of a pump become **gummed up,** they may be cleaned out by working a potash solution through the air cylinder. To do this, disconnect the air-discharge pipe at the main reservoir, and make provision for catching the solution as it is discharged through this outlet. Run the pump very slowly, and allow the potash to be drawn in through the air-inlet ports, and thus worked through the pump. Pass the same solution through four or five times, or until the passages are clean. Sufficient clean hot water must then be worked through the pump to thoroughly cleanse it of all potash, since, if any is allowed to remain, it will gradually work back into the brake system, destroy the gaskets, and work mischief in general. If a potash solution cannot be had, use hot soapy water, or even clear hot water alone.

RUNNING THE PUMP.

9. Starting.—When **first starting** the pump, the drain cocks *41*, Fig. 5, or *105* and *106*, Fig. 6, should be opened, and left so until the pump is thoroughly warm; it should be started slowly to allow the water of condensation to escape gradually, and to prevent pounding. No provision is made in the steam end of an air pump for bringing the piston to rest easily by means of cushioning, since, when the pump is working against pressure, the air in the air cylinder acts as a cushion. When the pump is first started, however, there is little or no pressure in the main reservoir, and, consequently, there is nothing to prevent the pistons from striking the cylinder heads

violently if the pump throttle is opened very wide. For this reason, the pump should be run slowly until sufficient pressure is accumulated to cushion the pistons—about 25 or 30 pounds.

After the pump is warm, the drain cocks should be closed, and the throttle may be opened wide enough to run the pump at the required speed. The air-pump lubricator should be turned on as soon as the pump is started, since, by oiling the cylinder well at the start, less oil will be necessary afterwards to keep it working smoothly. If a pump groans badly in the top end, the reversing piston probably needs oil; in this case, close the pump throttle, remove the reversing-chamber cap, and pour in a small quantity of good valve oil.

10. Speed of Pump.—To obtain the best results from a pump, it should not be run at a slower speed than from 45 to 60 strokes a minute. The speed may be increased as occasion demands, but "racing" should be avoided, as it causes overheating.

If a pump is run **too slowly**, some of the air, being compressed, will pass by the packing rings, and expand and fill the other end of the cylinder, and thus less fresh air will be drawn in through the suction valve at each stroke; in consequence of this, the pump heats up and its efficiency is greatly reduced. When the pump is run at its proper speed, however, the air has less time in which to pass by the piston packing-rings; consequently, the pump heats less and its efficiency is greater.

LIFT OF AIR VALVES.

11. The **lift** of the receiving air-valves in the 8-inch pump should be $\frac{1}{8}$ inch, and that of the discharge valves, $\frac{3}{32}$ inch. The lift of both the receiving and the discharge valves of the $9\frac{1}{2}$-inch pump should be $\frac{3}{32}$ inch. All the air valves in the $9\frac{1}{2}$-inch pump are of the same size; in the 8-inch pump, the receiving valves are smaller than the discharge valves, and, hence, must have a higher lift to accommodate the passage of the air.

WORKING TEMPERATURE OF PUMP.

12. Conditions Affecting the Temperature.—The **normal temperature** of a pump depends on: (1) the quantity of air it compresses; (2) the rate at which the air is compressed; (3) the pressure against which the pump works; and (4) the temperature of the air before compression.

1. *Quantity of Air Compressed.*—The greater the quantity of air compressed in a given time, the more continuously, or else the faster, the pump will have to work in order to compress it; hence, the greater the normal temperature of the pump.

2. *Rate of Compression.*—Experiment shows that the faster the air is compressed, the higher will be its final temperature; also, the faster the pump is run, the less time there is for the radiation of heat between strokes. Hence, since more heat is generated, and less heat radiated at each stroke of the pump, it is evident that the temperature of the pump must increase with its speed.

3. *Resisting Pressure.*—More power is employed when working against a higher than when working against a lower pressure; therefore, heat is generated at a greater rate. Also, experiment shows that the final temperature of air under compression increases with the pressure.

4. *Temperature of Air Before Compression.*—Experiment shows that air at 0° F. will have a final temperature of about 360° F. when compressed to 90 pounds pressure, while air at 100° F. will have a temperature of about 530° F., the speed of the compressor being the same in both cases.

EXCESSIVE HEATING OF PUMP.

13. Causes of Overheating.—The **overheating** of a pump may be due to one of the following causes: (1) Continuous high speed; (2) excessive pressure to work against; (3) air-piston rings badly worn; (4) air cylinder leaking; (5) main reservoir leaking back into air cylinder; (6) air passages in pump or air-discharge pipe partially stopped up; (7) air valves stuck shut; or (8) too small a main reservoir.

1, 2. *Continuous High Speed, or Excessive Pressure.*—It has already been shown (see preceding article) how either of these causes will result in excessive heating.

3. *Leaky Piston Packing-Rings.*—This defect will cause a pump to overheat more quickly and to a higher degree than any of the other causes; consequently, the air-piston packing rings should receive frequent attention.

When the packing rings are badly worn, air can pass by them in either direction; consequently, less air is taken into the cylinder and less forced into the main reservoir at each stroke than if the rings were tight. As the piston moves forwards, it compresses, and, therefore, raises the temperature of the air in front of it; some of this air then escapes past the piston, and raises the temperature of the incoming air considerably, *before it is compressed.* This results in a still higher final temperature of the air when compressed, and that portion which in its turn escapes past the piston is at a higher temperature, and, hence, heats the incoming air to a higher degree than in the previous stroke. At each stroke of the piston, the air that leaks by is hotter than in the previous stroke, and raises the temperature of the incoming air still more, until, finally, the pump is badly overheated.

There is also another effect due to leaky packing rings: Since the pump neither takes in nor discharges as much air as it would if in normal condition, it follows that a greater number of strokes will have to be made to pump up main-reservoir pressure; consequently, the pump will have to work faster or for a longer time than usual, either of which contingencies will help to overheat it.

To test for worn piston packing-rings run the pump at a speed of about 45 strokes per minute, and place the hand over the air-inlet ports. If on both the up and down strokes of the pump, air is drawn in during the first part of the stroke only, the suction ceasing during the latter part, it indicates that the packing rings need renewing. The reason why the suction ceases before the end of the stroke is as follows: As the piston moves forwards at the beginning of its stroke, a vacuum is created, and air is drawn into the cylinder behind it, but, as the piston

continues to advance, the air in front is gradually compressed until, finally, it is forced past the packing rings in sufficient quantities to destroy the vacuum and thus the suction.

4. *Leakage From the Air Cylinder.*—Any such leakage, either through a leaky or broken receiving valve, or a blow in the piston-rod packing, reduces the amount of air pumped per stroke, and the pump must either be run faster or for a longer time to compress a given amount.

A *leaky receiving valve* is indicated by air blowing back through the valve as the piston moves towards it. Also, it causes the piston to take a quicker stroke when traveling in that direction. *To test* for a leaky receiving valve in an 8-inch pump, hold the hand over the air-inlet ports; air will be forced out as the piston moves towards the leaky valve.

In the 9½-inch air pump (Fig. 6), the air for both ends of the air cylinder enters through the inlet *W*; consequently, air will be drawn in on both the up and the down strokes. Suppose the lower receiving valve *86′* to leak; then, as the piston moves towards the valve, it compresses the air in that end of the cylinder and forces some through the leak. This air, instead of being forced out of the inlet port *W*, passes up through the passage *F*, past the upper receiving valve *86*, and through port *m*, into the other end of the cylinder; consequently, less air is drawn in through the inlet port, to fill this end of the cylinder. [See view (*c*).] To test for a leaky receiving valve in the 9½-inch pump, therefore, run the pump slowly and place the hand over the inlet port; the suction will be less on the stroke *towards* the leaky valve. Also, the stroke *towards* the leaky valve will be quicker than the one from it.

5. *Back Leakage From Main Reservoir.*—This may be due to a broken discharge valve, to a defective valve seat, or to the valve being held from its seat by dirt or gum. Any of these causes will allow air to be compressed into the main reservoir, but, when the pump is reversed, the air will flow back through the defective valve and hold the receiving valve for that end of the cylinder to its seat; consequently, there will be no suction for that end of the cylinder. Also, the strokes of the pump will

be uneven, the one *towards* the defective valve being the slowest. If the upper discharge valve leaks, it will be indicated by a continuous discharge of air from the air-cylinder oil cup, if it is opened. If the lower discharge valve leaks, it will be indicated by a continuous discharge of air from the plug hole in lower cylinder head.

6. *Air Passages or Discharge Pipe Stopped Up.*—Occasionally the air passages or the air-discharge pipe become partly closed with gum and dirt. This increases the back pressure on the pump. It has also another effect: when the air-inlet passages are choked, the pump does not draw in as much air at a stroke as it should; while a choked discharge pipe increases the leakage past the piston rings, and more power is therefore necessary to force air into the main reservoir. These effects will cause the pump to run slower than usual, and heat up.

If the air valves have too little lift, the effect will be the same as though the air passages were choked. If only one of the valves has too little lift, the strokes of the pump will be uneven—the faster stroke being *towards* the defective valve, if a receiving valve, or *from* it, if a discharge valve.

7. *Air Valves Stuck Shut.*—If it is a receiving valve, there will be no suction as the piston moves away from it; the strokes of the pump will be uneven, the one towards the defective valve being the faster. The pump will probably pound on the fast stroke, and it will also become heated. The reason why the strokes are uneven is that the vacuum, formed in the end of the cylinder in which the stuck valve is, works *against* the steam pressure on the stroke away from the stuck valve, and *with it* on the return stroke. If both receiving valves are stuck, there will be no suction on either stroke of the pump; the pump will pound and heat, and the red hand of the gauge will not move forwards. The strokes, however, will be even, but the pump will run faster than usual. If the air-inlet ports become frozen or stopped up, the effect will be the same as though both receiving valves were stuck shut.

If a discharge valve is stuck shut, the strokes of the pump will be uneven, the *slow stroke* being *towards* the defective valve;

there will be less suction as the piston moves *away* from it, and the pump will heat. The reason why the strokes are uneven, is as follows: The cylinder is full of air as the piston starts towards the stuck valve, and, since the valve is closed and the air cannot escape, it is compressed and offers a steadily increasing resistance to the movement of the piston. The stroke away from the stuck valve is assisted by this compressed air, which acts like a compressed spring to force the piston along. As the force exerted by the air acts against the steam pressure in the first instance, and with it in the second, it is evident that one stroke will be faster than the other.

Should *both* discharge valves stick, the pump will run slower than usual and heat badly, and there will be no suction on either stroke, the piston simply churning back and forth in the cylinder. In this case, also, the red hand of the gauge will not move forwards. If the discharge pipe is frozen or stopped up, it will have the same effect as if both discharge valves were stuck shut. When the strokes of the pump are uneven, the pump is generally referred to as being "lame."

8. *Main Reservoir Too Small.*—The use of a **small main reservoir** in heavy freight service is very often the cause of the pump overheating, since it does not hold sufficient air to release the brakes and recharge the auxiliaries promptly, and the pump, consequently, must be worked faster when the brakes are released. A pump is not as efficient when hot as when cold, since air, on entering a hot cylinder, expands, and, consequently, less is required to fill it at atmospheric pressure; hence, the pump, when hot, must make a greater number of strokes, to do a given amount of work, than when cold.

POUNDING IN PUMP.

14. Usual Causes.—**Pounding** in an air pump may be due to any one of a number of causes. It may be due to water in the cylinder; to the pump being loose on the brackets that hold it, or the brackets being loose on the boiler; to the main piston striking against cylinder heads; to the nuts *58* of the

8-inch pump, or corresponding nuts on the $9\frac{1}{2}$-inch pump, working loose and striking the air-cylinder head; or to the air valves pounding on their seats, due to too much lift. In addition to the foregoing, the 8-inch pump may pound if the main valve strikes the stop-pin, or if the reversing piston strikes either the reversing-chamber cap, or the bottom of the reversing chamber itself.

Clearance in Pump.—The **clearance** in an air pump is purposely made as small as possible, the air as it is compressed in the air cylinder being relied on to act as a cushion for the pistons, to prevent their striking the cylinder heads. Packing rings that are badly worn, or receiving valves that are stuck, broken, or leaky, will destroy this cushioning effect of the air, and hence will allow the pump to pound. Also, the reversing plate, or the button on the reversing rod, may be so worn that the pump is not reversed in time to prevent the piston striking the heads and causing a pound.

Parts Too Long.—If either the stop-pin *50*, the main valve *7''*, or the stem of the reversing piston *23* is too long, it may make the main valve strike the stop-pin and cause a pound. The stop-pin is intended to prevent the main valve dropping down far enough (when steam is shut off) to allow the piston packing-rings to expand below the bushings and prevent the main valve rising.

The combined length of the main-valve spindle, reversing-piston stem, and stop-pin should be such that, when the reversing piston is bottomed on its bushing and the valve spindle is tight up against it, there will be about $\frac{5}{64}$ inch space between the bottom of the main-valve spindle and the stop-pin. When this space is provided, there will be no pounding of the main valve.

Reversing Piston Striking.—Before the reversing piston *23* can commence its upward stroke, the reversing valve *16* must close the steam port *a* in the upper steam-cylinder head and connect port *b* with the exhaust passage *c*. Therefore, as soon as the reversing piston, in moving upwards, closes the exhaust port *b*, the steam caught above it is compressed and forms a cushion

that brings the reversing piston and main valve to rest without pounding.

The small ports near the bottom of the reversing-piston bushing *22* connect the lower end of this bushing with the exhaust passage *f*. As soon as the reversing piston *23*, on its downward stroke, closes the lower one of these ports, it compresses the exhaust steam caught below it, and thus provides a cushion for this stroke. If, however, the packing rings are badly worn, the steam, instead of being compressed, will leak by them, thus reducing or totally destroying the cushion, and allowing the reversing piston to strike the cap, or the bottom of the bushing, as the case may be.

9½-INCH PUMP BLOWING.

15. Usual Causes.—A blow in the steam end of the 9½-inch pump may be due to: (1) a leak past the seat of the reversing valve *72*; (2) the reversing rod worn, and loose in the reversing-valve chamber cap; (3) a leak past slide valve *83*; (4) worn packing rings in either piston of the main valve *76*; (5) worn packing rings in steam piston *65*; or, (6) the gasket between the top cylinder head and the cylinder not making a tight joint.

1. *Reversing Valve Leaking.*—If the reversing valve *72* leaked through into port *f*, Fig. 6 (*b*), there would be a blow, since steam from the reversing-valve bushing would pass through ports *f* and *f′* and exhaust port *d* out into the atmosphere. This probably would be a light blow, however, and it would be continuous, since port *f* connects directly with the exhaust port *d*.

2. *Worn Reversing Rod.*—If the top of the reversing rod were worn so as to be loose in the cap nut *74*, steam could pass by the stem into the cap nut, and thence through port *x* and the passage that runs down alongside the reversing-valve bushing, into the top of the steam cylinder *61*. On the up stroke of the piston, this end of the cylinder is connected with the exhaust; consequently, the leak described would cause a constant, though light, blow during the up stroke.

3. *Slide Valve Leaking.*—If there were a leak past the slide valve *83*, it would cause a constant blow through the exhaust port *d* while the pump was working.

4. *Main-Valve Rings Blowing.*—Worn packing rings in piston *79* of the main piston valve *76* will also cause a constant blow at the exhaust during the time the pump is working, since chamber *E* is always connected with the atmosphere through the passage *t' t*, view (*d*). Chamber *B* (to the right of piston *77*) is connected with the exhaust only during the up stroke of the pump; hence, worn packing rings on piston *77* will cause a blow on the up stroke only.

5. *Steam-Piston Rings Blowing.*—Worn packing rings in steam piston *65* will cause a constant blow at the exhaust while the pump is working, since one end of the cylinder is always full of steam while the other end is connected to the exhaust, and steam can readily pass the packing rings. A leak past the steam-piston packing rings will generally produce the strongest blow of all.

6. *Leaky Gasket.*—The gasket between the top cylinder head and the cylinder may permit steam to escape into the exhaust passage *d' d''*, or into the steam passage *b' b''*. In the first case it will cause a blow on the down stroke only, since the upper end of the cylinder is connected to the steam supply on that stroke only. In the second case, the steam will escape from the upper end of the cylinder through the passage *b'*, port *b*, and out at the exhaust *d* to the atmosphere, on the down stroke. On the up stroke, steam will escape from the passage *b'*, through the leak in the gasket, into the upper end of the cylinder, and thence out through the exhaust. In the second case, therefore, the leak will cause a constant blow.

8-INCH PUMP BLOWING.

16. Usual Causes.—A blow will be produced in the steam end of the 8-inch air pump: (1) if the reversing valve *16* is worn so that steam can escape into the exhaust passage; (2) if the end of the reversing rod in the cap nut *20* is worn and allows steam to escape past it; (3) if the packing rings or the

pistons of the main valve *7*, or of the reversing piston *23*, are worn or broken; or (4) if the packing rings of the steam piston *10* are worn or broken.

1. *Reversing Valve Leaking.*—A constant blow will occur if the reversing valve is so worn that steam escapes through the ports *c*, *ff*, and *g* to the exhaust.

2. *Worn Reversing Rod.*—If the end of the reversing rod *17* in the cap nut *20* is worn, steam can escape by it and pass through the passage *x* into the upper end of the steam cylinder *3*. This will cause a blow on the up stroke, since the upper end of the cylinder is open to the exhaust on that stroke.

3. *Main-Valve Rings Blowing.*—If the packing rings in either of the pistons of the main valve are worn or broken, there will be a constant blow at the exhaust, since ports *f f* and *f′ f′* are always in connection with port *g*, which leads to the exhaust at *Y*.

Reversing-Piston Rings Blowing.—If the packing rings in the reversing piston *23* leak, there will be a blow on the up stroke, the steam escaping past the packing rings *24*, thence through the small ports at the bottom of the reversing chamber, and on through the passages *ff* and *g* to the exhaust at *Y*. The blow will occur only during the up stroke, since there is no steam in chamber *d* above the reversing piston during the down stroke.

4. *Steam-Piston Rings Blowing.*—If the packing rings of the steam piston allow steam to escape past them, a constant blow will be produced, as explained in connection with the 9½-inch pump.

9½-INCH PUMP STOPS.

17. Usual Causes.—It should be remembered that certain defects in the pump governor will cause the pump to stop. To determine whether or not the governor is at fault, open the drain cock *106*, Fig. 6; if steam escapes freely, the trouble is not in the governor.

But little trouble has been experienced with the 9½-inch pump stopping, about the only thing that will stop one of these

pumps being a bent or broken reversing rod *71*, or a bad leak between the steam passage *b' b''* and the upper end of the steam cylinder, due to a defect in the copper gasket between the head and the cylinder. The former prevents the pump reversing, while the latter allows live steam to enter the exhaust end of the cylinder at each stroke, which increases the back pressure against which the pump is working; consequently, if the pump is not in good condition and is working against a high main-reservoir pressure, it may stop.

18. A Former Cause of Trouble.—Trouble was experienced with some of the first $9\frac{1}{2}$-inch pumps, owing to the fact that the large piston *77* of the main valve could pass beyond and close the port *g''* in the bushing *75*, view (*d*). This prevented the admission of steam to chamber *B*, as a result of which the main valve was unable to take its stroke to the left, and the pump would stop. This was remedied by cutting a groove on the inside of the bushing, from port *g''* to the end; and, further, a steam space was provided behind the piston by turning the head down $\frac{1}{16}$ inch, except a portion at the center; thus, the steam can always pass freely to the back of the piston, which insures the valve making its stroke to the left, view (*a*). The tendency of the pump to stop at the top of its up stroke was thus overcome.

8-INCH PUMP STOPS.

19. Locating the Cause.—Since, in the 8-inch pump, there is no drain cock similar to *106*, Fig. 6, a different test must be made to determine whether the governor is reponsible for the pump stopping.

If the governor is operated by train-pipe pressure, close the cut-out cock *5* in the train pipe just below the brake valve, Fig. 1, and place the brake-valve handle in service position; this gradually reduces the pressure in the chamber *a* of the governor, Fig. 3; hence, the force exerted by the regulating spring *41* to close the pin valve *b* gradually increases. If the

pump does not start by the time the train-pipe pressure is fully discharged, the probability is that the pump, and not the governor, is at fault. Of course, if the governor has a relief port *c*, a constant blow from this port will indicate that the fault is in the governor.

If the governor is operated by main-reservoir pressure, close the cut-out cock as before, "lap" the brake valve, and then disconnect the air pipe from the governor at the union *z*. If the pump then starts, it indicates that the fault lies with the governor.

Another method that may be used when the governor is connected to either main-reservoir or train-pipe pressure, is to disconnect the steam-supply pipe to the pump at the union *X*, and note whether steam is supplied freely.

20. Usual Causes of Pump Stopping.—If the trouble is in the pump, it may be that: (1) the stop-pin *50* is broken or is too short; (2) the main-valve or reversing-piston packing rings are broken; (3) the reversing rod is bent or broken; (4) the reversing plate is loose or worn out; (5) the main piston-rod nuts are loose or broken; or, (6) the pump is very dry from lack of lubrication.

1. *Defective Stop-Pin.*—A stop-pin that is broken or is too short will allow the main valve to drop down sufficiently for the packing rings to expand below the bushings *25* and *26*. This will prevent the valve from taking an up stroke, and the motion of the pump cannot be reversed. In this case, steam will be admitted below piston *10* through the lower steam ports, and the pump will always stop on the upper end of the stroke.

Sometimes, in a case of this kind, the pump can be started by giving it steam and tapping lightly near the bushings. If this does not start it, and circumstances are such that the upper steam-cylinder head can be removed, it may be possible to forcibly raise the valve, although there is danger of breaking the packing rings or spiders in the effort.

If the valve cannot be raised in this way, the only remedy will be to remove the cylinder from the centerpiece and get at

it from below. This, of course, would not be attempted on the road.

If the main valve can be raised and the pump started, the governor should be cut out of service by means of a blind gasket, as explained in Art. 4, and care should be taken that steam is not again entirely shut off during the remainder of the run, as, otherwise, the trouble might occur again, especially if the main-valve rings are much worn.

2. *Main-Valve or Reversing-Piston Rings Defective.*—Cases have been known where broken main-valve rings have blocked the valve, and prevented its movement, thereby stopping the pump. A bad leak past the reversing piston, due to broken packing rings, will allow so much steam to escape that the pressure in chamber *d* will be reduced considerably, and a sufficient back pressure may be exerted on the under side of this piston to prevent the pump reversing its motion.

3, 4. *Defective Reversing Rod or Plate.*—A broken reversing rod, or a loose or worn-out reversing plate, will also prevent the pump from being reversed.

If, every time the pump throttle is closed for a few minutes and then reopened, the pump takes an up-and-down stroke and then stops, it is an indication that for some reason the reversing valve *16* has not moved to its lower position, and the pump should be examined for the cause.

5. *Loose Air-Piston Nuts.*—If the trouble is due to none of the above causes, remove the lower air-cylinder head and examine for loose or broken nuts *58* on piston rod, for pieces of broken air valve, or for dirt between piston and cylinder head, which prevents the pump completing its stroke and operating the reversing valve.

6. *Pump Run Dry.*—The part that is most affected when a pump is allowed to become very dry is the reversing piston, and this is consequently liable to stick and stop the pump for want of lubrication. A light tap will frequently start it again, in which case oil should be used freely to protect the pump against the possibility of cutting.

If either an 8-inch or a 9½-inch pump stops, it can, in most cases, be started again by first closing the pump throttle until all the steam in the pump has condensed, and then opening it quickly.

QUICK-ACTION TRIPLE VALVE.

TIME REQUIRED TO CHARGE AUXILIARIES.

21. The Effect of the Size of the Feed Groove.—The triple valve, like any other mechanism that is used under varying conditions, and is subject to rough treatment, is liable to certain disorders, and it is of these that we will now treat.

As soon as an engine is coupled to a train, the engineer charges the latter. Air from the main reservoir is forced back through the train pipe, thence through the feed grooves of the triples, and into the auxiliary reservoirs. The feed groove is made of such a size that, with a constant train-line pressure of 70 pounds, it will charge an auxiliary from 0 to 70 pounds in about 70 seconds. A train with fifty auxiliaries would charge as quickly as a single auxiliary, if the pump could keep the train-pipe pressure constant at 70 pounds; but, as it cannot do this, more than 70 seconds is required to charge the train. On a train of only four or five cars, the auxiliaries will charge in about the same length of time as a single auxiliary; but, with longer trains, the time of charging depends on the size and condition of the pump, the number of auxiliaries to be charged, and the extent of leaks in the train pipe and auxiliaries, etc.

The feed grooves in some of the first quick-action triples were made smaller than the present ones, and, consequently, one of these triples required about 2½ minutes to charge an auxiliary with a constant train-line pressure of 70 pounds. Many of the plain triples, on the other hand, had feed grooves that were too large for the volume of the auxiliaries they controlled; consequently, these auxiliaries could be charged in about 40 seconds under the same conditions.

22. Auxiliary Charges Too Slowly.—As already stated, the feed groove is of such a size that, with everything in good

condition, it will charge an auxiliary from 0 up to 70 pounds in about 70 seconds from a train-line pressure of 70 pounds. The time of charging, however, does not depend entirely on the feed groove; the auxiliaries may **charge more slowly** from any of the following causes: The small openings in the strainer of the drain cup, Fig. 1, or in the strainer *16* in the triple valve, Fig. 9, may be partially stopped up, so as to restrict the flow of air to the triple valve; the feed groove may be partially closed with gum or dirt; or the auxiliary reservoir may leak.

If oil, cinders, scale, pipe fins, etc. get into the train pipe, they may clog the strainers and feed grooves, get into the graduating valve and hold it from its seat, unseat the triple slide valve, or cause wear that will allow auxiliary pressure to escape to the atmosphere. Dirt and cinders will work into the train line if the brake hose is not hung up properly when not in use; scale may come from the inside of the pipes, if they are not properly treated before being applied to a car, or if they corrode; or oil may bake in the pump, and scale off, and work back into the brake system; also, pipe fins, if not removed by the pipemen, may work loose and cause trouble.

23. Effect of Working Conditions.—It will thus be seen that the conditions of strainers and triples may not be the same on any two cars of a train; hence, the time required to charge the different auxiliaries may vary considerably, and, when possible, sufficient time should be allowed for all the auxiliaries to become fully charged before the brake valve is placed on *lap*, or the brakes applied again. If the valve is *lapped* while some of the auxiliaries are undercharged, they will continue to take air from the train line until they equalize with it, and thus may reduce train-line pressure sufficiently to apply the brakes on the cars on which the auxiliaries were fully charged. On the other hand, if a service reduction is made while some of the auxiliaries are undercharged, the latter may not apply the brakes on their cars at the first reduction, and they will continue to take air from the train line until they equalize with it; in this case, the other brakes will set harder than is intended.

EFFECT OF TRAIN-PIPE AND AUXILIARY LEAKS.

24. Train-Pipe Leaks.—Leaks in the train pipe not only increase the time required to charge the auxiliaries, but, after the brakes are applied, they cause the triples to gradually apply the brakes harder, or, as is usually said, the brakes "creep on." A leak at any part of the train pipe affects all the triples, since the train pipe is continuous throughout the train.

25. Auxiliary-Reservoir Leaks.—As long as the brakes are off and the triples are in *release* position, the pump will make good any leakage of auxiliary pressure, and no harm will be done, aside from keeping the pump at work to supply the leak. When the brakes are applied, however, and the triple slide valves are in *service* position, a reduction of pressure in any auxiliary will allow train-line pressure to force its triple piston to release position, and release the brake on that car. Then, since the feed groove is open in this position, air from the train pipe will feed into the auxiliary to supply the leakage and to charge the auxiliary to train-pipe pressure; hence, a reduction will be made in train-pipe pressure, that will tend to apply the other brakes harder. It is possible, however, for the auxiliary reservoir to leak, and still not cause the brake to "leak off" or release. If train-pipe leaks reduce train-pipe pressure at the same rate that the leakage from the auxiliary reduces auxiliary pressure, the brake will not leak off; or, if the packing ring *6* is much worn, sufficient air may leak past into the auxiliary reservoir to supply the leakage and thus prevent the brake releasing.

Leakage of auxiliary air at the triple exhaust is generally due to dirt on the seat of the slide valve, a worn slide-valve seat, a leak in the gasket that is between the triple valve and the brake cylinder (see passenger equipment, Fig. 8) or in the gasket *15* that is between the triple valve and the auxiliary reservoir in the freight equipment, Fig. 10.

IMPORTANCE OF GRADUATING VALVE.

26. The graduating valve *7*, Fig. 9, is the part of the triple that makes it most sensitive. If there were no graduating valve, but simply the service or graduating port *z*, and the

slide valve were fastened firmly to the stem of the piston, the brakes could still be applied and released, but the triple valve would not be nearly so sensitive, and great reductions would be necessary to move the parts. For instance, when a reduction of train-pipe pressure was made, the triple would assume service position; but it would not assume lap position again until a sufficient difference of pressure existed between the auxiliary and the train line to allow the latter pressure to overcome the friction, not only of the triple piston packing ring, but also of the slide valve, in which case the latter would be forced back far enough to close the service port *z* (lap position). Then, when it was desired to apply the brake harder, a much greater train-pipe reduction than usual would be necessary to move the triple piston to service position again, since the auxiliary pressure would have to overcome the friction of the slide valve as well as of the triple piston.

TRIPLE-VALVE LEAKS AND DEFECTS.

27. Blow at Triple Exhaust.—If a blow occurs at the exhaust port of the triple, it may be caused by any of the following: (1) A leaky slide valve; (2) dirt on the seat of the emergency valve *10*, Fig. 9, or a worn-out rubber seat *11*; (3) a leak in gasket *14* between the passage *a* and the chamber *I*; (4) a leak of auxiliary air from chamber *Y* to the passage *d*, owing to defective gasket between brake-cylinder head and triple valve, Fig. 8; (5) a leak from the auxiliary through gasket *15* in the freight equipment; or (6) the pipe *b*, which leads from the triple through the auxiliary to the brake cylinder, might be leaking.

1. *Leaky Slide Valve.*—This will generally cause a blow at the exhaust port of the triple, regardless of whether the slide valve is in service or in release position, since, in either position, auxiliary pressure can feed across the face of the valve into the exhaust cavity *g*, and out to the atmosphere through ports *h* and *k* (see Fig. 9). With a leaking slide valve, the tendency for the brake, when set, is to release itself, since auxiliary pressure is, in that case, being reduced.

Dirt on the seat of this valve will cause a constant leak at the triple exhaust; it will also cause the brake to be very erratic in its action, as sometimes the slide valve will seat properly and the brake remain set, while, at others, the dirt will allow auxiliary air to escape to the atmosphere across the face of the slide valve, and release the brake after being applied. A thorough cleaning of the triple is the proper remedy in such a case.

2. *Emergency Valve Leaking.*—If the emergency valve leaks, the blow at the exhaust port will cease, as explained above, if the exhaust port is closed by applying the brake.

If a strong, heavy blow exists at the triple exhaust, and the brake will not release on that car, the emergency piston *8* is, perhaps, being held down so as to keep the emergency valve *10* unseated. In this position, the train-pipe pressure raises check *15*, air passes into the brake cylinder through the large ports faster than it can escape to the atmosphere through the slide valve and exhaust ports, and the brake remains applied, because air is entering the brake cylinder faster than it can escape. A light tap on the outside of the triple will generally cause the emergency valve to seat.

When the emergency valve leaks, there is a constant leak from the train pipe through the quick-action part of the triple into the brake cylinder. If the triple is in release position, the air feeding into the cylinder escapes to the atmosphere through the triple exhaust; if the brake is set, the air cannot escape, and the train-pipe and brake-cylinder pressures equalize and apply this brake hard. If the leaky triple is in a long train, in which the volume of train-pipe air is comparatively great, the brake cylinder will equalize at such a high pressure, on the first light service reduction, that the wheels on that car will probably be slid.

3, 4, 5, 6. *The Other Causes.*—When the triple is in release position, the leak will, in these cases, and also in case 2, allow air to reach the brake cylinder, and pass through the slide-valve exhaust cavity into the atmosphere; but, when the brake is applied, the exhaust cavity of the slide valve no longer

connects port *f* with the exhaust port *h*, and so the blow does not occur at the exhaust. In this case, the air continuing to leak into the brake cylinder will apply the brake harder. If auxiliary pressure leaks into the brake cylinder, the tendency will be to release the brake; while, if the train pipe feeds the leak, the brake will be set tighter, and the leakage will also tend to set the other brakes tighter by reducing train-pipe pressure.

Of the possible sources of leakage given, the two that are most frequently met with are the slide valve and the emergency, or rubber-seated, valve.

28. Other Common Defects.—The most common causes of trouble in the quick-action triple valve are: (1) strainers stopped up; (2) dirt on the seat of the graduating valve; (3) defective graduating spring; (4) triple gummed up; (5) broken graduating pin, and (6) triple freezing up.

1. *Strainers Stopped Up.*—Sometimes a triple valve will not set the brake on a car in response to either a light or a heavy train-pipe reduction. This may be due to the strainers being partly stopped up; or the triple may be so gummed up and dirty that the triple piston cannot move.

When a quick-action triple in a train applies a brake in emergency, the quick-action part of the triple takes air from the train pipe suddenly and puts it into the brake cylinder. This sudden reduction is sufficient to start the next quick-action triple into emergency, the next one following, and so on throughout the entire train. If two or three cars with dirty strainers, or a couple of old cars with plain triples, are placed together in a train, the sudden reduction made by the quick-action triple ahead of these will not be sufficient to work the next quick-action triple immediately behind them, owing to the effect of friction on the flow of air through the train pipe destroying the suddenness of the reduction; hence, the quick-action effect cannot be obtained on these cars or on the ones back of them. On the other hand, if the engineer makes an emergency application with this train, and laps the brake valve too quickly, the air from the rear cars will flow ahead and kick off the head-end brakes, and only a light service application will be obtained on

the brakes back of the ones causing the trouble. If the brake-valve handle is left in emergency position a sufficient length of time, however, full emergency action will be had on the cars ahead, and full service on those back of the ones causing the trouble.

2. *Dirt on the Seat of the Graduating Valve.*—This will produce no ill effect when the triple is in release position, as the service port *z* is then closed by the slide-valve seat, and it will make no difference whether the graduating valve is open or closed. In lap position, however, this will cause a leak, which will allow auxiliary air to escape through the graduating valve and ports *z* and *f* into the brake cylinder, thus applying the brake harder and reducing auxiliary pressure.

Whether or not this reduction of auxiliary-reservoir pressure will allow the brake to release will depend on the condition of the triple piston packing ring. If it is tight, auxiliary air will continue to leak into the brake cylinder until a sufficient difference of pressure exists between the train pipe and the auxiliary to start the slide valve moving, when it may move to release position and release the brake. If, however, air can leak by the piston packing-ring into the auxiliary reservoir as fast as it leaks by the graduating valve into the brake cylinder, the brake will continue to set harder instead of releasing. With a full application of the brakes, the auxiliary and brake-cylinder pressures are equal; therefore, under such conditions, a leaky graduating valve cannot release the brake unless the brake cylinder also leaks and reduces the auxiliary pressure at the same time.

3. *Defective Graduating Spring.*—The effect produced by a weak or broken graduating spring *22* depends on the length of the train. The duty of this spring is to prevent the parts of the triple valve from moving past service position, Fig. 9, view (*d*), during a service application of the brakes. If the spring is broken or is too weak to stop the parts at service position, and if the train is a short one of five cars or less, these parts will move to emergency position and apply the brake *quick action*, the other brakes, of course, following suit. With a long

train, on the other hand, the graduating spring can be removed entirely and not cause the brake to apply quick action.

The explanation of the foregoing is as follows: Since the graduating valve is open, auxiliary pressure begins to discharge into the brake cylinder as soon as port *z* of the slide valve arrives above port *f* in the seat. Now, whether the parts will move beyond this position and cause an emergency application of the brakes, depends on whether the train-pipe or the auxiliary pressure reduces the more quickly. A short train pipe contains a comparatively small volume of air; this discharging through the brake valve has its pressure reduced at a much greater rate than the auxiliary pressure that reduces through the graduating valve; hence, as soon as a sufficient difference in pressure is formed, the parts of the triple valve are moved forwards, and the brakes are applied in *emergency*. With a long train, however, the volume of air in the train pipe and the frictional resistance to its movement are so much greater that train-pipe pressure cannot be reduced through the train-pipe exhaust of the brake valve as fast as auxiliary pressure is reduced through the graduating valve. As a result, train-pipe and auxiliary pressures remain about equal, and a sufficient difference of pressure is not formed after service position is reached to move the parts of the triples to emergency position.

4. *"Sticky" Triples.*—A **sticky triple** is frequently the cause of the brakes applying quick action during a gradual train-pipe reduction. Generally, when a triple sticks, it does not respond to the first service reduction, nor, in some cases, to the second, and the brake on that car does not set; usually, with the next reduction, the difference in pressure between the auxiliary and the train line is such that the triple piston is torn loose from the gum and caused to move quickly forwards, compressing the graduating spring *22*, and moving the slide valve to emergency position. The sudden train-pipe reduction caused by the quick-action part of the faulty triple coming suddenly into play, starts the next triple into quick action, which affects the one following, and so on throughout the train.

5. *Broken Graduating Pin.*—If the pin that fastens the graduating valve *7* to the stem of the triple piston is broken,

the graduating valve will be held on its seat by auxiliary pressure, and the brake on that car will not apply until a sufficient reduction is made to move the triple slide valve to emergency position, when it will set quick action. With a light service reduction, the triple assumes service position, but the graduating valve being on its seat, no air can pass from the auxiliary to the brake cylinder, and the brake does not apply on this car. With only a light reduction, the auxiliary pressure acting on the triple piston is not sufficient to compress the graduating spring, but, when a second train-pipe reduction is made, the auxiliary presssure is sufficiently greater than that in the train pipe to force the triple piston out and compress the graduating spring, and the triple then assumes emergency position. If the graduating valve is so badly gummed up that air can only escape very slowly through it, the effect will be the same as though the graduating pin were broken.

6. *Triple Freezing Up.*—Water sometimes accumulates in the drain cup of the triple valves. In cold weather, this water may freeze and cause trouble. In thawing out a triple, always remove the drain plug and drain off the water to avoid a recurrence of the trouble. The water found in the brake system comes mostly from the moisture drawn into the pump along with the air; as the air is compressed, this moisture is given up, and some of it works back into the brake system.

29. Locating the Cause of Trouble.—To locate a sticky triple, or one with a broken or badly gummed-up graduating valve, make a service reduction that is not quite sufficient to cause the defective triple to operate quick action, and then look for the brake that has not set. Cut this one out, and repeat the test to make sure the trouble has been properly located. If all brakes go into emergency with the first light service reduction, the only way to locate the faulty triple will be to first close an angle cock in the middle of the train, and try to locate the trouble in one half first; then proceed in the same manner with the half that is known to contain the faulty triple, and so on until the search has been narrowed down to four or five cars. The brakes

may then be applied and the pistons of these cars watched to see which one jumps first, or the cars may be cut out one at a time until the trouble is located.

PLAIN TRIPLE VALVE.

WHERE USED.

30. The plain triple valve, Fig. 7, is usually found only on engine, tender, and old passenger-car equipments. The parts of this triple correspond to the service parts of the quick-action triple, and they are liable to the same disorders. The graduating spring *10* in the plain triple serves the same purpose as the one in the quick-action triple, but it is comparatively of little importance, since, when a plain triple goes into emergency, it does not affect the other triples, as it does not take air from the train pipe.

LEAKS AND OTHER DEFECTS.

31. **Leaks.**—Among the most common sources of trouble in the plain triple are leaky slide and graduating valves, or a blow at the exhaust port.

Leaky Valves.—A leaky slide valve or graduating valve will affect the brake in the same manner as the same defect in a quick-action triple would.

Triple Exhaust Blowing.—A blow at the exhaust port *k* may be caused by a leaky slide valve *3* or plug cock *13*. As in the case of the quick-action triple, there will be a continuous blow at the exhaust port if the slide valve leaks, regardless of whether the brake is applied or released. If the plug cock *13* leaks, and the slide valve is in release position, air from the train line entering at *W* will leak by the plug valve into port *e*, thence through port *f*, cavity *g* of the slide valve, and ports *h* and *k*, to the atmosphere. If the brake is set, the slide valve will be in such a position that cavity *g* will be closed to port *f*, and the blow at the exhaust will cease; but the air leaking by the plug cock will pass out to the brake cylinder at *X* and set

this brake tighter. With the plug cock leaking, the train-pipe and brake-cylinder pressures will gradually equalize, and, on a long train having a large volume of air in the train pipe, the train-pipe and brake-cylinder pressures might equalize sufficiently high to slide the wheels.

32. Other Defects.—Under this heading may be mentioned defective rings and the freezing up of the triple.

Defective Rings.—A worn piston packing-ring *6* will allow air to feed by the piston, and may charge the auxiliary too quickly. On a long train, a slow train-pipe reduction might allow auxiliary pressure to feed back through the feed grooves *m* and *n*, and past the packing ring, sufficiently fast to keep equal with train-pipe pressure, in which case the triple piston would not be forced out, and the brake would not apply; or in releasing brakes, if train-pipe pressure is increased slowly, it might feed by the packing ring sufficiently fast to charge the auxiliary and leave the brake set.

Triple Freezing Up.—Water may collect in chamber *A*; in cold weather, therefore, the latter should be drained frequently by partially unscrewing the lower cap nut *11*.

CARE OF TRIPLES.

33. Triple valves should be inspected and thoroughly cleaned and oiled at least once every six months. In **cleaning the triple,** it is a good idea to immerse the triple piston in kerosene while cleaning the other parts. The emergency parts of the quick-action triple should be removed, examined, and cleaned, and then replaced without oiling, as these particular parts are seldom used, and oil would only serve to collect dirt. The slide valve and the chamber in which it works should be thoroughly cleaned, and great care should be exercised to remove any lint from the valve or its seat. The graduating valve and all small ports should be carefully cleaned. After everything else has been attended to, the triple piston packing ring should be cleaned carefully, *without being removed from the piston*, as in so removing it there is great danger of springing

the ring out of true. Before replacing the piston, the ring should move freely to the touch, and in entering the piston into its bushing, care should be taken not to bruise the packing ring.

The graduating stem should be forced in with the thumb to make sure that the graduating spring is doing its work properly. The only parts of the triple that need oiling are the triple piston packing ring, the bushing in which it works, and the face of the slide valve; sufficient oil can be held on the end of the finger to oil these parts. Too much oil is a detriment rather than a benefit, since it collects scale and dirt. The strainer in the triple, and the one in the train-pipe tee, where the branch pipe couples on, should always be kept clean.

FREIGHT EQUIPMENT.

LEAKS AND OTHER DEFECTS.

34. Leaks.—In addition to the causes of trouble already given as occurring in the triple itself, the freight equipment shown in Fig. 10 is liable to various leaks, as follows:

Defective Gasket.—The gasket *15* between the triple valve and the auxiliary may leak, allowing air to pass from the auxiliary into pipe *b*, and thence to the brake cylinder; or, from the auxiliary to the atmosphere. The leak between the auxiliary and the brake cylinder will cause a blow at the triple exhaust port when the triple is in release position. After the brake is applied and the triple is in service position, however, the leakage of auxiliary air across the gasket, either to the brake cylinder or the atmosphere, will tend to release the brake.

Pipe Leaking in Auxiliary.—If pipe *b* leaks inside of the auxiliary, the same effect will be noticed as if the gasket *15* leaked between the auxiliary and pipe *b*.

Leaky Valves.—A leaky release valve *17* will allow a constant escape of auxiliary air to the atmosphere. With the triple valve in release position, the pump will supply this leak and no ill effect will be noticed aside from the extra work put on

the pump; when the brake is applied, however, the escape of air reducing the auxiliary pressure will tend to release it.

35. Other Defects.—There are also certain other defects of the various parts that may give trouble.

Split Sleeve.—The sleeve *3* sometimes splits, owing to the side motion of the push rod that works inside it. When this occurs, the release spring cannot force the brake piston to release position when brakes are released, as it binds in the hood of the cylinder; consequently, the brake shoes tend to drag on the wheels.

Defective Spring.—If the release spring *9* is weak, it will not force the brake piston to release position properly, especially if the cylinder is somewhat dirty; as a result of this, the piston may stay out after the triple has moved to release position and allowed the air to escape from the cylinder. In such a case, the sleeve and piston will gradually work in when the car is moving, since the jar of the wheels against the shoes will work them away, and cause the rods and levers to assume their normal release positions.

Defective Packing.—If the packing leather *7* is cracked or worn through on the bend of the flange, it will be impossible to set that brake and keep it on, for, as the air enters the cylinder, it will escape past the piston, and the brake will gradually leak off. Sometimes a brake in this condition will not apply with a service application, but will do so with an emergency application, after which it gradually leaks off.

Leakage Groove Stopped Up.—If the leakage groove *a* becomes stopped up with dirt or gum, and the piston travel happens to have been taken up short enough, the pressure on the brake piston may get so high that the wheels on this car may slide when the brakes are applied. If such a car were near the rear of a long train, the train pipe of which leaked, the reduction due to the leak might work the triple piston out far enough to close the exhaust port and allow some of the auxiliary-reservoir air to reach the brake cylinder. The air feeding in slowly would blow through the leakage groove were it open; but, being

closed, the brake of this car would gradually apply and might stall the train.

Expander Ring Out of Place.—The duty of the expander ring *8* is to hold the flange of the packing leather against the walls of the cylinder. If the expander ring worked out, due to its not being put in properly, the flange of the leather would drop down, and all air entering the cylinder would probably escape past the piston to the atmosphere.

CARE OF EQUIPMENT.

36. Cleaning and Oiling the Cylinder.—When the cylinder head and piston are removed, the walls of the cylinder should be thoroughly cleaned with waste saturated with kerosene, and special care should be exercised to free the leakage groove of all dirt or gum; the cylinder should then be wiped dry.

The expander ring should be removed, and both that and also the groove in which it rests be thoroughly cleaned; then, before the ring is replaced, a small amount of oil should be put into the groove. Before replacing the piston, the cylinder walls should be thoroughly oiled or greased, by covering the hand with the oil or grease and then rubbing the walls with the hand. When the cylinder is oiled through the oil plug *16*, care should be taken not to put in so much that, when the piston is moved to release position, the oil will be forced through pipe *b* into the triple, as this will decay the rubber-seated valve and render the triple useless until repaired.

37. Cleaning and Oiling Triples.—In cleaning and oiling triples, *all* parts should be thoroughly cleaned. It is not necessary to oil the emergency parts, and sufficient oil can be held on the end of the finger to oil the slide valve, its bushing, the triple piston packing ring, and the bushing in which it works. The strainer, where the branch pipe couples to the triple, should also be cleaned, as well as the one where the branch pipe joins the main train pipe.

RETAINING VALVE.

ITS DUTY AND OPERATION.

38. Duty.—The primary object of the retaining valve is to retain a pressure of 15 pounds in the brake cylinder, during the time the triple is in release position, while the engineer is recharging the auxiliaries in descending a grade. It has no effect whatever on any brake except that of the car on which it is placed, and it only affects the releasing of that brake, since it merely retains 15 pounds pressure in the brake cylinder.

The retainers, however, often perform another duty, namely, to keep the slack of a freight train bunched after brakes have been released, and the train is drifting preparatory to making a stop. Two or three of the head-end retainers judiciously used in such a case will often prevent a bad jar at the rear of a train.

The retainer is used on almost all cars in freight service, and, in mountainous districts, on passenger cars also. A retainer when in service holds 15 pounds pressure in the brake cylinder, while the brake is released, regardless of whether the piston travel is long or short.

39. Testing.—To test a retaining valve, the handle should be turned up and the engineer then signaled to apply and release the brakes. Shortly after air ceases to discharge from the retainer, the handle should be turned down, and, if air discharges through port *e*, the retainer may be considered to be all right.

40. Use on Grades.—In using the retaining valves on a grade, it is best not to raise the handles until the train is rounding the summit of the hill. If the retaining handles are turned up before the summit is reached, and the leakage groove in any of the brake cylinders should happen to be stopped up, any leak that would allow air pressure to reach that cylinder would set the brake, and perhaps stall the train.

GAINS DUE TO USE OF RETAINING VALVE.

41. The following remarks will give an idea of the **gain effected** by using the retaining valve in handling trains on grades: With train pipe and auxiliary fully charged, and the piston travel adjusted to 8 inches, a 5-pound train-pipe reduction will give a brake-cylinder pressure of about 10 pounds; with this brake full-set, a pressure of about 50½ pounds is developed in the brake cylinder. If the retainer handle is now raised, and train-pipe pressure is increased so as to force the triple-valve piston to release position, the auxiliary will be recharged to 70 pounds, *while the brake cylinder will retain 15 pounds.* This will cause the brake cylinder and auxiliary to equalize on succeeding applications at about 56 pounds, instead of 50, as long as the retaining valve is cut in. This not only gives a greater braking power, but also saves air, since a reduction of only about 15 pounds is necessary to make a full application of the brakes. Then again, with 15 pounds already in the brake cylinder, a 5-pound reduction will give a brake-cylinder pressure of about 38 pounds. It is thus seen that by using retainers, a large gain in braking power is made with the first 5-pound reduction, a gain is made when the brake is full-set, less air need be wasted to apply the brake in full, and less time is required to recharge after a release is made.

With the piston travel adjusted to 8 inches, an emergency application without a retaining valve develops about 57½ pounds in the brake cylinder, while, with a retaining valve, a brake-cylinder pressure of about 62 pounds is developed. This also shows a slight gain in favor of the retaining valve.

The gain made with a 5-pound train-pipe reduction, after the retaining valve is cut in, appears, at first glance, to be out of proportion, but it should be remembered that, when the retaining valve is not in use and a train-pipe reduction is made, part of the first auxiliary air that enters the brake cylinder escapes through the leakage groove to the atmosphere, before the piston has moved out far enough to close it. Some air also blows past the packing leather before the flanges are forced tightly against the cylinder walls. This loss does not occur

when the retaining valve is in use, as the 15 pounds retained by it holds the piston out far enough to cover the leakage groove; it also holds the flanges of the packing leather against the cylinder walls.

It will thus be seen that a retaining valve is not only an aid in controlling the speed of the train while on a down grade, during the time the pump is recharging the auxiliaries, but it is also an adjunct that causes a more powerful braking force to be developed while it is in use.

The figures given are for a retaining valve that holds the full 15 pounds in the brake cylinder. This amount has been found by repeated tests to be the standard pressure for cars in interchange service. This pressure gives good results in braking on long grades, without excessive heating of wheels.

LEAKS AND DEFECTS.

42. The retaining valve, Figs. 12 and 13, will be *rendered useless* by any of the following defects: (1) A leak at the union in the retainer pipe near the triple valve. (2) A leaky plug cock *6* that allows the pressure that should be retained in the brake cylinder to leak by the plug valve into port *e*, and thence to the atmosphere. (3) Dirt on the seat of the weighted valve *4*, which will hold the valve from its seat and allow the air to pass by the valve and out to the atmosphere at port *d*. (4) A leak at the joint where the retainer screws on to the retainer pipe, which also allows the brake-cylinder pressure to escape to the atmosphere. (5) A split in the pipe leading to the retaining valve, or a leaky packing leather in the brake cylinder; either of these defects will produce the same effect as an imperfect retaining valve. (6) Port *d* being stopped up; for all the air will be retained in the brake cylinder when the brakes are released, and, consequently, the brake will remain set with full force. (7) If the retaining valve is not placed perpendicularly on the car, the weight will not hold the valve on the seat, and air will leak past.

D-8 BRAKE VALVE.

DEFECTS.

43. Testing Excess-Pressure Spring.—If the pump is started with the brake valve in full release, both red and black gauge hands should *move up together*, as, in this position, main-reservoir, equalizing-reservoir, and train-pipe pressures are all directly connected. If the gauge hands do not stay together, the gauge is incorrect, and should be reported for adjustment. With this valve, the pump governor is operated by train-pipe pressure; consequently, it stops the pump when train-pipe pressure reaches 70 pounds, and, with the brake valve in release position, both hands of the gauge should register this amount when the pump stops.

If the pump is started with the valve handle in *running* position, the red hand should be 20 pounds in advance of the black one; and, when the pump stops, the black hand should register 70 pounds and the red hand 90. If the black hand indicates 70 pounds, but the red hand indicates less than 90, the excess-pressure spring *20*, Fig. 14, is either too short or too weak. If the black hand stands at 70 pounds and the red above 90, the excess-pressure spring is too stiff, or the valve *21* needs cleaning, to make it work more freely.

Should the spring *20 break*, lengthen the longer piece by stretching until it will hold the excess-pressure valve to its seat with sufficient force to maintain, as nearly as possible, the proper excess pressure. If the spring breaks near the middle, it may be necessary to force a small piece of wood into the valve *21*, so as to partially fill it and thus compensate for the short spring. The broken spring should be replaced by a new one at the first opportunity.

If the spring is *too weak*, it should be removed and lengthened by stretching until of the proper strength. If *too stiff*, it should be shortened by cutting off a piece. If, when the pump stops, the black hand registers either more or less than 70 pounds, and the red hand shows that the proper excess pressure is maintained, then the pump governor needs adjusting. To do this,

remove the cap nut *39*, Fig. 3, and unscrew the nut *40* to adjust for a lower train-pipe pressure, or screw it down for a higher pressure.

44. Brake Valve Fails to Maintain Excess Pressure. If, with the valve in running position, both hands remain together all the time, and no excess pressure is maintained, the trouble is caused by a leaky rotary valve or by dirt on the seat of the excess-pressure valve *21*. Sometimes this leak from the main reservoir into the train pipe is so slight that it does not affect the excess pressure when the engine is coupled to a train; but, when the engine is alone, no excess pressure can be maintained, as the train pipe equalizes with the main reservoir. In the former case, leaks out of the train pipe compensate for the slight leak into it; while, in the latter, the train pipe is so short that practically no air leaks out, in which case the leak into it soon causes the train pipe and main reservoir to equalize.

45. Testing for Leaky Rotary.—To test for a leaky rotary, close the cut-out cock below the brake valve, and start the pump with the valve handle on lap position. In this position all ports are blocked, and any leak into the train pipe will cause a blow at the train-pipe exhaust, or will be indicated by the black hand of the gauge.

A method that can be used when the brake system is charged is to make a service reduction of 30 or 40 pounds, close the cut-out cock *5* in the train pipe under the brake valve, and lap the valve; then, any leakage of main-reservoir air into the train pipe will be indicated by a blow at the train-pipe exhaust.

Still another method is to fully charge the main reservoir and place the brake valve on lap; drain all air from the equalizing reservoir, the engine and tender auxiliaries, and the train pipe, and see that all bleed cocks are closed; then open the angle cock at the back of tender, and place the end of the hose in a pail of water. Any leakage of main-reservoir pressure into the train pipe will be indicated by bubbles rising to the surface of the water. Although this method will detect a smaller leak, the others are sufficiently accurate, and can be tried more easily.

EXCESS-PRESSURE VALVE FAULTS.

46. Dirt on Valve Seat.—If the rotary does not leak, the trouble must be in the excess-pressure valve. In fact, dirt on the seat of the excess-pressure valve is generally found to be the source of trouble when excess pressure cannot be maintained.

47. Removing the Valve.—If necessary to remove the excess-pressure valve *21*, for cleaning or otherwise, close the cut-out cock *5* under the brake valve, Fig. 1, and place the valve in service position before attempting to remove it. Closing the cut-out cock retains the air in the train pipe and auxiliaries; while placing the brake valve in service position closes port *f* to main-reservoir pressure, and empties chamber *D* and the train pipe above the cut-out cock *5*, thus removing all pressure from the excess-pressure valve. The valve may then be removed by unscrewing the cap nut *19*. *Clean both the valve and its seat thoroughly*, being careful not to scrape the face or seat of the valve with any hard material. Before replacing, place the brake-valve handle in running position for a second or two, to blow out any loose dirt or scale that may be in the ports leading to the valve.

48. Valve Stuck Shut.—Occasionally, the excess-pressure valve becomes stuck shut, so that air cannot pass through it into the train pipe when the brake valve is placed in running position. This results usually from the use of too much or poor oil in the air end of the pump; the oil forms a gum that gradually blocks the excess-pressure valve and may also cause trouble in other parts of the air-brake system. With the excess-pressure valve stuck, the engineer very often goes over the road with the brake-valve handle in full release, and with no excess pressure. This is a very bad practice and one that should be avoided. If the excess-pressure valve sticks, take it out and clean it. This can be done in a few minutes, and will cause very much less delay than if it were allowed to remain stuck and the valve carried in full release, as in the latter case the brakes are liable to stick after each application. If the

excess-pressure valve *21 works stiffly* in the cap nut *19*, the valve will be less sensitive than usual and the excess pressure will fluctuate; that is, when the valve works stiffly, more than 20 pounds excess pressure must be obtained before it will open, while, on the other hand, it will not close until the excess pressure is less than 20 pounds.

49. Leaks.—A leak in the rotary valve or past the excess-pressure valve that will allow train-pipe and main-reservoir pressures to equalize, will maintain them equal; and, since with this brake valve the governor is set to stop the pump as soon as a train-pipe pressure of 70 pounds is obtained, the pump will not start again until the pressure in both train pipe and main reservoir is reduced to that amount. Thus, a considerable reduction in train-pipe pressure must take place, which is very liable to cause the brakes to "creep on."

50. High Excess-Pressure.—If this brake valve is lapped before train-pipe pressure is obtained, the governor will not stop the pump, which will continue to operate until sufficient main-reservoir pressure is accumulated to stop it. With a high excess pressure, as in this case, care must be exercised in releasing the brakes; that is, do not leave the valve too long in release, for, if the main reservoir were allowed to equalize with the train pipe and auxiliaries, they would be charged to such a pressure—especially with a short train—that it would be liable to burst some of the hose or else slide the wheels when the brakes were applied. On some roads a duplex pump governor is used to prevent overcharging—one side being set at 70 pounds and operated by train-pipe pressure, the other being set at 90 pounds and operated by main-reservoir pressure. In this way, the pump is stopped as soon as either the main reservoir or the train pipe is charged to the desired pressure. This practice gives very good results.

51. Rotary Valve Turns Hard.—When the rotary valve is hard to turn, it does not necessarily indicate that the valve needs oiling. The nut that holds the handle *8* on may be screwed down so tight that the gasket *12* binds.

52. Peculiarity of D-8 Valve.—A peculiarity of this brake valve is that, if placed in a position midway between the service and the emergency positions—in which position the direct-application-and-supply port *l* is connected by cavity *c* of the rotary valve with the exhaust port *k*—the black hand of the air gauge, instead of dropping back to zero, will indicate the amount of pressure in the main reservoir.

The reason for this is that, in this position, port *j* of the rotary valve is directly above port *g* in its seat; consequently, the equalizing reservoir equalizes with the main reservoir, and, since the black hand indicates the pressure in the equalizing reservoir, it must, in this position, indicate main-reservoir pressure also.

PORT h AND PORT-AND-GROOVE e.

53. Size of Port h.—The hole through the plug in port *h*, view (*b*), is made of such a size that equalizing-reservoir pressure will be reduced from 70 to 50 pounds, in service position, in from 4 to 5 seconds. If it takes longer than this, the packing ring in the equalizing piston is probably so loose that the train-pipe pressure leaks into chamber *D* above the equalizing piston, or else the preliminary-exhaust port *e*, view (*c*), is partially closed with dirt or gum. If port *e* is closed entirely, a service application cannot be made with the brake valve.

54. Small Groove in the Rotary Seat.—This groove, which connects with port *e*, is made of such a length as to connect chamber *D* with the main reservoir (through port *j* and the groove-and-port *e*) from the instant the train line is connected with main reservoir through port *a*, cavity *c*, and the supply port *l*, view (*c*). The combined area of the ports *e* and *g*, which lead to chamber *D*, is such that, ordinarily, chamber *D* will charge as fast or faster than the train pipe. Without the groove, however, the train pipe would be connected with the main reservoir—through port *a* and cavity *c*—both before port *j* made connection with port *e*, in moving the valve *to* release position, and also after it had broken connection with

this port in moving *from* release position. At such times, therefore, train-pipe pressure would generally increase faster than the pressure in chamber *D*; consequently, a discharge would probably occur at the train-pipe exhaust valve for an instant or two, while moving the brake valve into release position.

RECHARGING SHORT TRAIN.

55. When the train pipe is short, as, for instance, on a lone engine and tender, a discharge generally occurs at the train-pipe exhaust valve for a second or two when the brakes are released. The reason for this is that the capacity of the train pipe is small, while the ports through which it is charged are large compared with the area of the ports through which chamber *D* is charged; hence, the pressure in the train pipe increases faster than that in chamber *D*, and therefore raises the equalizing piston. This opens the train-pipe exhaust valve *E*, and a discharge takes place until train-pipe pressure is reduced below the pressure of chamber *D*, after which the valve is closed. This will occur with either a D-8 or an F-6 brake valve.

With a long train pipe, this discharge does not take place, for the reason that the volume to be filled is so much greater that the pressure in chamber *D* increases faster than train-pipe pressure; consequently, the equalizing piston is held on its seat.

F-6 BRAKE VALVE.

TESTING.

56. Testing the Gauge.—If the pump is started with the brake valve in *full release*, the hands of the air gauge will *move up together* until they both register full main-reservoir pressure. The pump governor, when used with this valve, is operated by main-reservoir pressure, and does not stop the pump until main-reservoir pressure is obtained; consequently, the gauge hands will move up together and register the same pressure when the pump stops, since, in release position, there

is a direct connection between the train pipe and the main reservoir. If the hands do not move up together, the gauge is incorrect and should be reported.

If the pump is started with the brake valve in *running position*, the hands of the gauge will move up together until full train-pipe pressure is obtained; the feed-valve attachment then closes and the black hand, consequently, remains stationary, but the red hand continues to move up until full main-reservoir pressure is obtained.

57. Testing the Pump Governor.—If, with a correct gauge, the black hand indicates 70 pounds when the pump stops, while the red hand indicates either more or less than proper main-reservoir pressure, the pump governor needs regulating. This is accomplished by removing the cap nut *39*, Fig. 3, and slacking the regulating nut *40* to regulate for a lower, or screwing it tighter for a higher, main-reservoir pressure.

58. Testing the Feed-Valve Attachment.—If the red hand indicates the main-reservoir pressure correctly, but the black hand indicates either more or less than 70 pounds, then the feed-valve attachment needs regulating. This is accomplished by removing the cap nut *71*, Fig. 16 (*b*), and slacking the regulating nut *70* to reduce, or screwing it up to increase, the train-pipe pressure.

LEAKS AND OTHER DEFECTS.

59. Feed Valve Fails to Maintain Train-Pipe Pressure.—If, in running position, the feed-valve attachment fails to maintain train-pipe pressure at 70 pounds, and the black hand gradually moves up until it indicates the same as the red hand, the trouble is due to a leak from the main reservoir into the train pipe, either through the rotary valve, the gasket *32*, the supply valve *63*, or by the feed-valve case gasket *27*.

60. Leaky Rotary Valve.—A leak in the rotary valve generally occurs past the bridge *w*, so that main-reservoir pressure can pass down port *a* and leak into cavity *c* of the valve, thence passing to the train line through port *l*. Any leak from

the main reservoir into the train pipe, therefore, tends to release the brakes when they are applied. The test for a leaky rotary of an F-6 valve is the same as with the D-8.

61. Leaky Gasket.—A leak in the gasket *32* generally allows main-reservoir pressure to pass from the passage $X\ x'$ into chamber D above the piston *17*, view (*a*). Since the capacity of the equalizing reservoir is small, such a leak will cause the black hand to quickly move up to the position of the red hand when the brake valve is lapped. It will also make the service reductions slower than usual, since the air feeding into chamber D tends to maintain the pressure there, and, if the leak were a very bad one, it would prevent any service reduction being made at all. With chamber D pressure greater than train-pipe pressure, as in the above case, air will leak past the equalizing piston packing ring *18* into the train pipe.

Testing for Leaky Gasket.—A leak in gasket *32* may be detected by placing the brake valve on lap and watching the gauge; if the gasket leaks, the black hand will move up rapidly towards the red hand. A leak through the rotary valve or the gasket *32* can be readily distinguished from a leak in gasket *27* or supply valve *63*, since the former are constant while the two latter occur only when the brake valve is in running position.

62. Leak Past the Supply Valve.—A leak past the supply valve may be due to a leaky valve, to the valve being held from its seat by dirt or gum, or to a defective diaphragm *72*, view (*b*). To determine which of these is causing the trouble, the supply valve must be removed and inspected.

To remove the valve, close the cut-out cock *5* under the brake valve, Fig. 1, and place the brake valve in service position, so as to remove all pressure from the feed-valve attachment. Unscrew the cap nut *65*, and remove the supply valve *63*.

To clean the valve, soak it in kerosene, or heat it in steam, and then wipe dry with clean cloth or waste. The valve seat may be cleaned with a piece of wood.

The face of the supply valve is made of soft metal, and, therefore, should never be scraped with any hard tool, as the

valve may thus be ruined. In case of a leaky supply valve, grind it to a tight fit by placing carefully on its seat and turning with the fingers while applying a light pressure. The spring box *69* must be taken out and the piston *74* pulled down so as to allow the supply valve to rest firmly on its seat. Do not use emery, as it is unnecessary and will cause trouble if it gets into the brake system. The supply valve cannot stand much grinding. Before replacing the supply valve, put the brake valve in running position for a second or two, to blow out any loose dirt there may be around the supply-valve seat.

63. Defective Diaphragm.—The edges of the diaphragm *72* may be so crushed and squeezed out, if the spring box *69* is screwed up too tight, that the diaphragm will "arch up" and thus almost entirely prevent movement of the feed-valve piston *74*; consequently, the supply valve will be held from its seat. The spring box *69* should only be screwed up until a firm joint is made with the diaphragm, and not until it makes a tight joint with the feed-valve case *62*.

If the trouble in the feed-valve attachment is in the gasket *27* or the supply valve *63*, it may be readily repaired while on the road, but if in the diaphragm *72*, repairs had better not be attempted until the end of the run. In this case, no excess pressure can be carried, and train-pipe pressure will have to be regulated by means of the pump throttle.

64. Feed-Valve Piston Sticking.—Trouble is sometimes experienced in removing piston *74*, on account of its sticking. In such a case, proceed as follows: Remove the supply valve *63* as described, and replace the cap nut *65*; unscrew the spring case *69*, grasp the stem *66* of the piston in the right hand, and move the brake-valve handle carefully to running position. Main-reservoir pressure acting on top of piston *74* will blow it out. When replacing the piston, be sure that packing ring *67* works freely, and do not bruise it by pounding in getting the piston back.

65. Leaky Feed-Valve Case Gasket.—A leak sometimes occurs in the gasket *27*, between the feed ports *f′ f″* and *i*, which allows main-reservoir air to pass directly into the train

pipe when the brake valve is in running position. This can sometimes be stopped by simply tightening the nuts of the feed-valve studs, view (*e*). If it cannot, then close the cut-out cock under the brake valve, place the valve in service position, remove the feed-valve case from the brake-valve body, and replace the blown-out gasket with a temporary one made of pasteboard, part of an old felt hat, or of anything similar that is at hand.

66. Leaky Train-Pipe Exhaust Valve.—Sometimes the train-pipe exhaust valve *E* is held from its seat by dirt or gum. This causes a continual blow at the exhaust valve, and, consequently, when the brake valve is on lap the brakes will gradually set harder. It may be possible to close the train pipe exhaust valve by quickly moving the brake valve from full release to emergency and back again a couple of times. If not, the equalizing piston will have to be removed and cleaned.

67. Preliminary-Exhaust Port Plug.—The size of the passage through the plug in preliminary-exhaust port *e* is such that, during a service reduction, equalizing-reservoir pressure should be reduced through it from 70 to 50 pounds, in about 5 seconds. If it does not, the trouble is due to one of the following causes: Either the size of this passage is reduced owing to the presence of gum and dirt; or, the piston packing-ring *18* is so worn that train-pipe air can pass by it into chamber *D*; or, the gasket *32* is leaking.

CARE OF ENGINEER'S VALVES.

68. General Remarks.—There is a wide range of variation in the time a rotary valve will continue working satisfactorily in general service. Some valves will run three, four, or six months, while others will not run as many weeks.

Tallow or *vaseline* are good lubricants for the rotary, but oil of any kind should be used sparingly on any part of the brake apparatus, except the steam end of the pump. Oil that has a tendency to gum should never be used.

Whenever the rotary valve works hard, the brake valve should be taken apart and the rotary cleaned and oiled, to prevent cutting. At the same time, the packing ring *18* should be cleaned, but without removing it, since, if removed, it is liable to be sprung out of true, which will necessitate refitting to the bushing in which it works. Also clean the stem and seat of the valve *E* thoroughly, but leave no oil on either, as it will catch particles of dirt and scale and cause trouble.

69. Rotary Working Hard.—The chief causes of a rotary working hard are: too free use of oil on the air end of the pump, or the use of poor oil; constant use of the emergency position of the valve, which tends to draw dirt and scale from the train line upon the rotary seat; a hot pump, the heat from which will cake the oil on the rotary seat; the nut *7*, Fig. 16 (*b*), or the corresponding nut in Fig. 14 (*a*), being screwed down so tight as to cause gasket *12* to bind on the top casing of the engineer's valve.

70. Cleaning the Feed-Valve Attachment.—In cleaning the feed-valve attachment of the F-6 valve, or the excess-pressure valve of the D-8 valve, remove all dirt and gum and clean the valve chambers thoroughly; then blow out, by turning the brake valve to running position. Any gum present should be softened, if possible, and wiped out instead of scraping out with a tool that is liable to scratch the valve seat. The packing ring *67* of the feed-valve piston *74* should be cleaned *without removing*, and then oiled a little. In putting the parts together, do not screw the nuts that fasten the rotary-valve handle too tight; and, in screwing the lower casing *69* of the feed-valve attachment on the F-6 valve, be sure that there is an opening of about $\frac{1}{32}$ of an inch between the upper and lower parts of governor body, since screwing the lower part up tight crushes the gasket, as already explained.

THE EQUALIZING RESERVOIR.

ITS IMPORTANCE.

71. The equalizing reservoir plays a very important part in the handling of the brakes in service applications. The duty of this reservoir, as explained in Art. **75,** Part 1, is to increase the capacity of chamber *D* in the brake valve an amount sufficient to enable small service reductions to be made, so as to apply the brakes gradually.

EFFECTS OF LEAKS.

72. Slight Leaks.—A slight leak in the equalizing reservoir or its connections constantly tends to reduce the pressure in chamber *D*; the effect of such a leak depends on the position of the brake-valve handle.

In full-release and running positions there would practically be no effect, aside from the fact that a little extra air would have to be supplied by the pump.

When the valve is moved to service position, the leak acts to help the reduction made by the engineer, and, consequently, a harder application of the brakes than is intended will be made.

When the valve is moved to lap position, the leak continues to reduce the pressure in chamber *D*; train-pipe pressure then raises the equalizing piston and escapes to the atmosphere, and this sets the brakes harder. A slight leak from the equalizing reservoir, therefore, causes a blow from the train-pipe exhaust valve when the brake valve is in lap position, and the longer the train pipe, the stronger the blow will be.

73. Bad Leaks.—A bad leak, such as would be produced by a split or broken pipe to the equalizing reservoir or air gauge, will allow chamber *D* pressure to escape entirely, and the train-pipe exhaust valve will be held open by train-pipe pressure until it has all escaped. This will result in a full application, or, in some cases, an emergency application of the

brakes. Such a leak, therefore, will render the brake system useless until it is stopped.

Leak in Equalizing Reservoir.—If the leak occurs in the equalizing reservoir, or in the pipe leading to it, place a blind gasket in the union at *T* of the brake valve, Figs. 14 and 16, plug the train-pipe exhaust elbow *25* (which is threaded for this purpose), and then use the brake valve carefully in emergency position (like the old three-way cock) in making service stops. In all other respects, the brake valve should be operated as usual, since placing the gasket and plug in the places mentioned does not affect its working in release, lap, running, or emergency positions.

Defective Gauge Pipe.—If the leak is due to a split or break in the pipe leading to the air gauge, the trouble may be remedied by putting a blind gasket in the union *W* of the brake valve. This will cut out the black hand of the gauge, but will not in any way affect the working of the brake valve.

It is an interesting experiment to put a blind gasket in the union *T*, where the pipe from the equalizing reservoir connects with the brake valve, and notice the effect of a service reduction when the engine is connected, first to a train of seven cars or less, and then to a train of considerably more than seven.

MAKING SERVICE STOPS FROM EMERGENCY POSITION.

74. Considerable care and judgment must be exercised in making service stops from emergency position. If the exhaust port is opened *too wide*, or opened or closed *too rapidly*, trouble is almost sure to follow. The exhaust port should be opened *very gradually* and just sufficiently wide to make, as nearly as possible, the usual train-pipe reduction; if opened wider, too great a reduction will be made and rough handling of passengers or freight will probably result.

Opening Exhaust Port Too Rapidly.—If the exhaust port is opened too wide or too rapidly, a quick reduction is made in the forward end of the train line, which may operate the emergency part of the triple—if it does not, it sets the front-end

brakes before the back-end ones; and the longer the train pipe, the greater this effect will be. This tends to retard the front cars, and the rear ones, which are not retarded, crash into them with great force if the train is very long, and damaged draft-rigging or freight is the result.

Closing Exhaust Port Too Rapidly.—If the exhaust port is closed too quickly, the forward brakes may be "kicked off." When once in motion, the long column of air in the train pipe cannot be stopped instantly; consequently, if the exhaust port is closed very rapidly, the air will continue to flow forwards after it is closed and may raise the pressure in the front end of the train pipe sufficiently to release or kick off the forward brakes. If the exhaust port is closed so quickly that the train-pipe pressure is not equalized the whole length, the triple valves on the front end will equalize the auxiliaries and train pipe at a lower pressure than on the rear cars, and, when the train-pipe pressure finally equalizes the whole length, the pressure in the train pipe on the head cars will be greater than in the auxiliaries on those cars, thus causing the triples to move to release position and release some of the head brakes.

THE AIR BRAKE.

(PART 3.)

OPERATING AND TESTING.

THE MAKE-UP OF A TRAIN.

1. The smoothness and ease with which a freight train can be handled, as well as the facility with which it can be stopped by means of the air brake, depends, to a considerable extent, on the way the train is **made up**. The make-up of a passenger train, on the other hand, affects the handling of the train so very slightly that, so far as the braking is concerned, no particular attention need be paid to it.

GENERAL CONSIDERATIONS.

2. The conditions of braking on passenger and freight trains differ greatly. On a passenger train there is no free **slack** between cars to bother us; both the load and the braking power are distributed quite uniformly throughout the length of the train; the brakes are kept in good condition and the piston travel maintained within proper limits; train-pipe, auxiliary, and brake-cylinder leakage is very slight; and the length of the train pipe is such that, practically, the brakes set simultaneously on all parts of the train.

With a freight train, on the other hand, there is a great deal of slack, which must be handled properly to avoid severe shocks; the load is generally distributed unevenly throughout the train; the brakes generally do not receive sufficient attention

to keep them in as good condition as those on a passenger train; and the brake-piston travel is seldom uniform. Consequently, the braking force, even on an all-air train, is not uniform throughout its length; the leakage in the brake system is greater in freight than in passenger service; and, lastly, the train pipe on a freight train is generally so long that the retarding effect of friction on the flow of air through it is sufficient to cause an appreciable interval of time to elapse between the operation of the first and last brakes. The increased diameter of the freight-car train pipe helps this last trouble in a measure.

3. Effects of Slack.—There is always a great deal of free slack in a freight train, and it must be handled with great care or else severe shocks will result, which may injure both drawbars and freight. The slack is less troublesome on all-air than on part-air trains, since in the former each car is equipped with the air brake, which permits of the retarding force being applied to, or removed from, each car at nearly the same instant; the slack, therefore, cannot gather or run out quickly, and shocks when they occur are less severe. However, a large number of freight trains are in operation that have only a part of the cars equipped with air brakes, and with these the effect of slack is most severe.

The engineer has more or less direct control over the slack that is between the **air cars**, but he has no control over that between the **non-air cars**; consequently, the free slack back of the air cars must be "taken up" every time the brakes are applied, and be run out at every release. Whether a shock will occur either in "bunching" or "stretching" a train, depends on how quickly it is accomplished. If the first service reduction is made sufficiently heavy to bunch the train quickly, the last cars will run up against the others with great force; and the heavier the last cars are loaded, the greater will be the shock and consequent damage. On the other hand, the lighter the rear cars, the less the shock will be; hence, a part-air train can be handled more easily and with less chance of damage to freight if the heavily loaded cars are placed next to the air cars, and the less heavily loaded ones and empties next to the way car.

4. Effects of Unevenly Distributed Load.—When a freight train is made up of both loaded and empty cars, and the loaded cars are distributed haphazard throughout the train, the load is said to be *distributed unevenly.* Since it is harder both to start and stop loaded cars, shocks of a more or less serious nature occur at different points of the train every time it is started, stopped, or has its speed retarded suddenly. This trouble can be avoided by placing all loaded cars together at the head end of the train.

5. Effects of Unequal Piston Travel.—To effect smooth handling of freight trains by means of the air brake, it is essential that the travel of the brake-cylinder pistons be kept within the proper limits. If the **piston travel** on some of the cars in a train is too short, while on others it is too long, shocks will occur at a number of points in the train every time the brakes are applied or released. This is due to the fact that the brake cylinders having a short piston travel apply their brakes harder at each reduction and equalize with their auxiliaries sooner, and at a higher pressure, than those having a long piston travel; also, they release later than the long-travel brakes. This causes the slack to be gathered at some parts of the train, and to run out at others, every time the brakes are applied or released, producing a surging of the cars that results in shocks, which make smooth handling of the train difficult.

6. Effects of Length of Train Pipe.—The **length of train pipe** also has considerable influence on the ease with which the train can be handled. Frictional resistance tends to retard the flow of air through the train pipe, and the longer the train pipe the more troublesome this retarding effect becomes. When conditions are normal, the retarding effect is such that in making an ordinary service reduction on a fifty-car air freight train, the pressure in the head end of the train pipe is reduced about 6 pounds before the reduction begins to be felt at the rear end; while, on releasing brakes on such a train, there may be a difference of pressure of about 10 or 12 pounds between the

two ends, the pressure at the head end being the higher. This difference of pressure causes the head-end brakes to both apply and release sooner than the rear-end ones, with the result that, on a long train, some severe shocks will be produced if the brakes are not handled with skill and judgment.

MAKING UP FREIGHT TRAINS.

ALL-AIR TRAIN.

7. **All-air trains** can be handled much more smoothly and satisfactorily if all the loaded cars are placed next to the engine, and the empties next to the way car. Also, when the cars are mostly equipped with quick-action triples, care should be taken not to place two or three cars together that either have plain triples, or have their brakes cut out, or are merely piped, since, in cases of emergency, it will be impossible to obtain the quick action of the triples back of them.

PART-AIR TRAIN.

8. In making up a **part-air train,** all the air cars, whether loaded or empty, should be placed together at the head end of the train and cut into service. Every air brake possible should be employed in braking, since the more in use the more smoothly the train can be handled; besides, they may be needed to make a quick stop in an emergency. Do not place together three or four cars with plain triples, or with brakes cut out, if most of the cars have quick-action triples, but distribute them among the quick-action cars. As to the non-air cars, the best results will be obtained if they can be so arranged that the loaded ones are next to the air cars and ahead of the empties. Empty non-air flat cars are liable to be damaged if placed ahead of loads next to the air cars; they should come next to rear end.

TESTING BRAKES.

ENGINE EQUIPMENT.

9. The Air Pump.—Any defects in the engine air-brake or signal apparatus should be reported at the end of the trip, so that the necessary repairs can be made before the engine is again called into service. If necessary, tests should be made to locate the defects.

The air pump should be tested under its usual head of steam, as follows: With the pump running at normal speed, note the time at intervals of 10 pounds, while the main-reservoir pressure is being raised from 40 to 90 pounds. If the pressure is pumped in the usual time, during which the pump shows no sign of disorder, the presumption is that it is in good condition and no further tests will be necessary. If, on the other hand, the test shows that the pump is not in its normal condition, the trouble may be due to leaky piston packing-rings, to leaky receiving valves, to back leakage from main reservoir, or to the air valves being stuck. Tests, as in Art. **13**, Part 2, should be made to locate the cause.

10. The Pump Governor.—The governor should be tested to see whether standard pressure is obtained when it stops the pump; also, to see whether it will start the pump promptly when a light reduction of not more than 2 pounds is made in the pressure that operates the governor (see Art. **28**, Part 1). If the pump stops either before or after standard pressure is obtained, the governor should be adjusted, by means of the regulating nut *40*, until it regulates the pump properly (see Art. **57**, Part 2). If the governor does not start the pump promptly when a slight reduction is made, it may be due to a leaky pin valve, to the relief port *c* being stopped up, or (in governors not having this relief port) to the governor piston packing rings being too tight (see Art. **2**, Part 2).

11. The Brake Valve.—The brake valve should first be tested for leaks from main reservoir into the train pipe. In the D-8 valve this would occur past the rotary valve, so that a test

for a leaky rotary should be made by one of the methods given in Art. **45,** Part 2. In the F-6 valve, the leak may occur either past the rotary valve or the gasket *32*. Tests for these defects are given in Arts. **60** and **61,** Part 2. Next, if the valve is of the D-8 type, the excess-pressure spring should be tested to ascertain if it is of the proper resistance, as in Art. **43,** Part 2; or, if the valve is of the F-6 type, test the tension of the regulating spring *68* in the feed-valve, as in Art. **58,** Part 2. Then, if a D-8 valve, test for a leak past the excess-pressure valve, Art. **49,** Part 2; or, if an F-6 valve, test for a leaky supply valve and leaky feed-valve case gasket, Arts. **62** and **65,** Part 2.

Next make a service reduction of 20 pounds in chamber *D*, and note the time required for the reduction. If it takes longer than 5 seconds, the indications are that the size of the passage in the preliminary-exhaust port is reduced; or the piston packing-ring is worn; or, in the F-6 valve, the gasket *32* is leaking (see Arts. **53** and **67,** Part 2). If the reduction is made in much less time than 5 seconds, it indicates either that the equalizing reservoir leaks, or that there is water in it. For a test for leaks in the equalizing reservoir, see Art. **72,** Part 2.

12. Driver and Tender Brakes.—An air gauge should be attached to the driver- and tender-brake cylinders at least once a month, to ascertain the condition of the piston packing leathers. After the auxiliaries are fully charged, make a 35- or 40-pound service reduction, lap the valve, and note the pressure at which the auxiliary and brake cylinders equalize. Also, note the pressure at the end of 5 minutes; if it does not decrease more than 5 or 6 pounds during that time, the brake cylinder is in good condition. If the gauge shows that the brake-cylinder pressure decreases at a considerably greater rate, examine the packing leathers and look for leaks in the cylinder connections, the gasket between the cylinder and head, and the piston-rod packing.

If the driver-brake cylinder is in such a position that it is subjected to considerable heat, it should be oiled sufficiently often to keep the packing leather soft and pliable. It is poor practice to use water to soften the packing leather, since it dries

out very quickly and the leather then becomes harder and is much more liable to crack.

Driver Brake Fails to Apply.—If the driver brake fails to apply, first see whether the handle of the cut-out cock is turned so as to cut out the brake. The brake being cut in, open the release cock on the auxiliary to see whether it is charged. If the discharge indicates that the auxiliary is charged, it may be that the triple piston, being badly gummed, is stuck in the release position, or that its packing ring is badly worn. In either case, when a reduction is made, the auxiliary may equalize with the train pipe through the feed groove and past the packing ring so fast that the piston is not moved out. In case the triple piston is stuck, one or two sudden heavy reductions should loosen it. If the cause cannot be located, take down the triple and examine it. Also, examine the brake-cylinder packing leathers, as a leak there is a cause for failure to apply.

Driver Brake Fails to Release.—This may be due to a worn piston packing-ring in the triple valve, aided by dirt and gum, the leakage past the packing ring allowing auxiliary pressure to equalize with the train line without moving the triple piston; or the triple exhaust port may be stopped up; or the release spring in the brake cylinder may be weak or broken; or, in the cam brake, the piston travel may be so long that the brakes lock against the drivers. In the latter event, the cams must be pried until the brake releases. In the event of the brake being stuck, try to release it by making a heavy reduction and then quickly placing the brake valve in full-release position.

Driver Brake Releases.—If the driver brakes release soon after being applied, it may be due to a leak in the auxiliary reservoir or its connections, to a leaky graduating valve in the triple valve, or to a leak in the piston packing leather or piston-rod packing. See also, Art. **74**, Part 2.

13. Triple Valves.—Plain triples are used on the engine and tender; therefore, if a blow occurs at the exhaust port of either triple, look for a leaky slide valve *3*, or for a leak past the plug cock *13* into port *f*, Fig. 7, Part 1. To determine which of

these is causing the blow, apply the brake lightly; this causes the slide valve to close communication between port *f* and the exhaust port *k*, and if the trouble is due to a leaky plug cock, the blow will cease, while if due to a leaky slide valve, it will continue.

The method of testing the air-signal system for defects will be given after the signal system has been explained.

TERMINAL TEST OF TRAIN.

14. General Instructions.—If possible, all the air cars should be coupled up and the brakes cut in before the engine is connected to the train, as both time and air can be saved by so doing.

On taking his engine, the engineer should start his pump and run it slowly until sufficient pressure is accumulated in the main reservoir to properly cushion the pump; he should then increase its speed and pump up the proper main-reservoir pressure. Also, he should carefully inspect the air-brake apparatus on both the engine and tender, to assure himself that all necessary repairs have been made, and that everything is in perfect working order. The train pipe on the engine should be blown out to get rid of any dirt and water there may be in it before the engine is coupled to the train. The brake valve should be carried in lap position* while the engine is being coupled to the train. After coupling the hose between engine and train, the tender angle cock should be opened first, so that the hose will be charged when the car angle cock is opened. If the car angle cock is opened first and the train is short and equipped with quick-action triples, the brakes are liable to apply quick-action, due to the sudden reduction caused by train-pipe air expanding to fill the empty hose. The angle cocks should always be opened slowly, since, if the handle is turned quickly, emergency action may result.

*There is considerable difference of opinion as to the position in which the valve should be carried when coupling to the train, but the consensus of opinion seems to favor lap position.

During the time the train is being charged, the inspector, or trainman, should pass along and examine each car for leaks and other defects. It should be observed whether all of the angle cocks are open, except the last one on the rear air-braked car; whether the cock in each branch pipe is open so that all of the cars, except those that are not in good condition, are cut in; whether the hand-brakes are fully released; and, if the retainers are to be used, whether the retainer handles are turned up.

After the train has been fully charged to standard pressure, the brake system should be tested. If time will permit, 70 pounds pressure should always be obtained before this test is made; but in no case should it be made with less than 60 pounds for passenger trains or 50 pounds for freight trains. When the train is fully charged, it will be indicated by the pump slowing up.

To make the test, a service reduction of from 5 to 7 pounds, or one just sufficient to move the brake pistons out past the leakage grooves, should be made, and the brake valve lapped. The engineer should then watch the air gauge to ascertain the extent of train-pipe leaks, since they will be indicated by the black* hand falling. A sufficient number of moderate service reductions should then be made to produce a 20-pound train-pipe reduction, and the brakes should then be held on while the train is inspected to see whether all brakes set or whether any of them leak off after being set; also, the length of the piston travel on each car should be examined. After the entire train has been inspected, the engineer should be signaled to release brakes, and, if the train is equipped with the air-signal system, the signal should be given from the rear car to make sure that the air signal is connected up and working properly. The engineer should then release the brakes, and, if the retainers were not in use, the train should again be inspected to see whether all brakes release properly and whether there is a blow at the exhaust port of any of the triple valves. If the retainer handles were turned up during the test, the inspector or brakeman should go over the train after the engineer has released, and

* The train-line hand on the new semaphore gauge is *white*.

turn the retainer handles down, noting, as he turns each down, whether the brake releases, and whether a blow occurs at retainer after brake has released. If air discharges from the retainer as the handle is turned down, the retainer is working properly. After the test, a report should be made to both the engineer and conductor, showing the total number of air and non-air cars in the train; the number of air cars in good working order and the number cut out; the condition of the piston travel; the number of retainers, if they are to be used, that are working properly; and also, the general condition of the train.

In making the first service reduction in testing the brakes, the engineer should note the *length of time* the train-pipe exhaust blows, as by making a practice of so doing, he soon will be able to judge of the length of train pipe that is cut in, and thus, in many instances, can detect an angle cock that has been left closed. He should also note if the sound of the train-pipe exhaust is full and continuous, or strong at first and then stringing out weak for some seconds; a little practice will teach him to distinguish the effect of a partly opened angle cock or a stoppage in the train pipe.

15. Brake Fails to Apply.—If, during the inspection, a brake is found that **will not set**, first make sure that it is cut in, and then try the bleed cock on the auxiliary reservoir, to ascertain whether the reservoir has been charged. If the auxiliary is not charged, and there is sufficient time at disposal, take the triple down and look for a stopped-up feed groove. If air issues freely from the bleed cock, it may be that the feed groove was only partially stopped up, resulting in the auxiliary being charged insufficiently to set the brake when the test was made. If the trouble cannot be remedied at the time, cut out the brake by closing the cut-out cock in the branch pipe leading to the triple.

16. Brake Releases.—If a certain brake **will not stay on,** but releases as soon as it is set, the trouble is due to a heavy leak either from the brake cylinder or from the auxiliary reservoir. If the leak is from the auxiliary, the triple valve will move to release position, and air from the brake cylinder

will come out of the exhaust. If the leak is in the brake cylinder only, the triple valve will not move. The leak from the brake cylinder may occur through the leakage groove or past the piston in the brake cylinder. The hand-brake may be partly set, or the slack in the brake may be taken up so short that the brake-cylinder piston cannot move out far enough to cover the leakage groove, in which case the brake will either not set, or will release at once. The leak past the brake-cylinder piston may be due to a dried-out packing leather, or to the expander ring being out of place.

Leaks from the auxiliary reservoir may occur through a defect in the release valve (Art. 34, Part 2) or through the triple exhaust port (Arts. 25 and 27, Part 2). If at the release valve, look for a bent valve rod or for dirt on the valve seat. A leak due to the former may be remedied by straightening the valve rod; that due to the latter can in some cases be remedied by quickly jerking the release valve open two or three times. If the leak cannot be stopped, the brake must be cut out.

17. Brake Fails to Release.—If a brake **fails to release**, and there is a strong blow at the exhaust port of the triple valve, the trouble is caused by a bad leak past the rubber seat of the emergency valve, or else the valve is stuck open (see Art. 27, Part 2). In either case, train-pipe air enters the brake cylinder at a faster rate than brake-cylinder air can escape through the exhaust port, and consequently pressure accumulates in the cylinder and holds the brake on. If the trouble does not cease when the triple is jarred lightly with a piece of wood, make a quick, heavy reduction, and then release; if this does not prove effective, cut out the brake by closing the cut-out cock, drain the auxiliary reservoir by means of the release valve, and then cut the brake in suddenly. If the blow still continues, cut the brake out of service.

If, when the brake refuses to release, there is no blow at the triple exhaust, first see if the handle of the retainer on that car is turned down, and, if so, whether the retainer exhaust port is stopped up. A certain kind of wasp has been known, in some

localities, to build its nest in the retainer and thus plug it up. The retainer being all right, see whether the hand-brake is fully released; whether the slack has been taken up too tight; or whether the brake has released, but the spring in the brake cylinder been unable to move the brake piston to release position. If the trouble is not in any of these places, it is pretty sure to be due to a badly worn packing ring in the triple piston.

Testing Triple Piston.—The condition of the triple piston packing ring can be determined as follows: Apply the brake by making a 10- or 12-pound reduction, and then gradually open the release valve on the auxiliary of the defective brake a very small amount, so that a slight discharge takes place through it. If the brake does not release within 10 or 15 seconds, gradually open the release valve a little wider, so as to increase the rate of discharge. Continue to increase the discharge every 10 or 15 seconds until the brake releases; then the rate at which air is escaping through the release valve will be a measure of the rate at which train-pipe air escapes past the triple piston packing ring. The escape of air through the release valve, however, must be slightly greater than that past the packing ring, as otherwise a sufficient auxiliary reduction could not be obtained to release the brake. When the packing ring is worn, train-pipe pressure must be increased quite rapidly to move the triple to release position; in such a case, therefore, the brakes are more liable to stick on a long, than on a short, train.

If the engineer finds that some of the brakes have a tendency **to stick,** he should carry the full amount of excess pressure all the time, and, at places where a heavy application must be made, he should have a high main-reservoir pressure to insure a prompt release.

18. Train-Pipe Leaks.—In inspecting a train for leaks, the parts to be inspected may be divided into: (1) the train pipe and its branch pipes; (2) the hose and couplings; (3) the triple valves; (4) the auxiliary reservoir; and (5) the brake cylinder.

1. *The Train Pipe and Branch Pipes.*—Leaks in the train pipe may occur at any of the joints. If at the union joint at the car drain cup, it can sometimes be stopped by tightening that joint; if not, a new gasket must be used. When the leak occurs at the joint where the branch pipe screws into the car drain cup, or in the joints at the stop-cock in the branch pipe, it can sometimes be stopped by disconnecting the branch pipe at the triple valve and turning the pipe until the leak ceases. If the leak occurs in the union at the triple, it may be stopped by tightening the union joint or by replacing the union gasket.

The leak may be due to a split or break in the train pipe. In that case, switch the car behind all of the air cars and couple its hose to that of the last air car; then close the front angle cock on the defective car and open the rear one on the car ahead, so that the hose will be included in the train pipe. Then, should the train part between the defective car and the last air car, the brakes will be applied.

2. *The Hose and Couplings.*—In looking for leaks in an air-brake hose, not only the hose but also the couplings and nipples should be examined. The hose itself may be porous, in which case the air escapes so silently and in such finely divided streams that it is very liable to be overlooked, especially as the hose may have the appearance of being perfectly sound. In some cases, such a hose can be detected by bringing a lighted torch near it, or by wetting the hand and moving it over the hose, the escaping air making the hand feel cooler. The best method, however, is to apply a little soap and water by means of a sponge or piece of waste; the escaping air will be indicated by the formation of bubbles. Such a hose, when located, should be removed and marked "defective," a sound hose being put in to replace it.

Leakage at the hose coupling may occur past the gaskets *2*, or under the hose clamps *c*, Fig. 11, Part 1. If in the gaskets, close the angle cocks on either side of the hose, separate it, and if the gaskets have been distorted out of shape, straighten them out and try them again. If they still leak, new gaskets should be used. If none are at hand, separate the couplings and put a match or small sliver of wood back of each lug and again unite

the couplings. This will force the gaskets closer together, and will probably stop the leak. Sometimes the manner in which frozen couplings are parted is the cause of trouble with coupling gaskets. **Frozen couplings** should always be thawed out before an attempt is made to part them, as otherwise the gaskets are almost sure to be ruined. Paper should never be used between the hose gaskets to stop a leak, as it is very liable to work into the brake system and cause trouble. If the leak is under the hose clamp *c* and cannot be remedied by tightening the clamp, a new hose must be substituted.

Leakage at the hose nipple may be due to the nipple not being screwed into the angle cock tight enough, or the leak may occur under the nipple hose clamp. If the former, screw up the nipple until it makes a tight joint; if the latter, tighten the clamp, and if this does not stop the leak, change the hose.

3. *The Triple Valves.*—A blow at the triple exhaust port may be due to a leak either from the train line or from the auxiliary reservoir. To test for the source of the blow, close the stop-cock in the branch pipe so as to cut out the brake: if the leak is from the train line, the brake will set; if from the auxiliary reservoir, it will not. The exhaust port of the triple valve or of the pressure retainer must never be plugged up on account of a blow occurring at either place, for the reason that it would then be impossible to release the brake on that car.

4. *The Auxiliary Reservoir.*—Leakage from the auxiliary reservoir may occur through either the release valve or the triple exhaust port, as already mentioned.

5. *The Brake Cylinder.*—Brake-cylinder leakage was discussed in Art. **35**, Part 2. If the leakage is very great, the brake should be cut out of service.

19. Cutting Out a Brake.—When, on account of some defect in the apparatus, it becomes absolutely necessary to cut a brake out of service, proceed as follows: If a quick-action brake, close the cut-out cock in the branch pipe of the triple valve; if a plain triple is used, first release the brake so that the brake piston moves back and uncovers the leakage groove, turn the handle *15* (Fig. 7, Part 1) to the position *15'*, that is,

midway between the horizontal and vertical positions. The release valve of the auxiliary reservoir must then be opened and secured in that position, if a freight car, so that the reservoir will be relieved of all pressure; otherwise the brake is liable to set and cause trouble. Never attempt to cut out a brake by closing the angle cocks at the ends of the car, as that will not only cut out the brake on that car, but on all others back of it, since closing an angle cock cuts off the train pipe back of it.

20. Cutting Out a Car.—A brake is cut out by closing the stop-cock in the branch pipe. A car is cut out by closing the angle cocks at each end of the car, the release valve being opened the same as when a brake is cut out. After a car has been cut out, it should be switched to the rear of the air cars, and its front hose coupled into the train pipe for the reasons just given in Art. **18**, 1.

RUNNING TEST.

21. A **running test** of the brakes should be made on all trains when leaving the terminal station, to make sure that the brakes set and release properly throughout the train. A running test should also be made when, for any reason, a train is parted during the run.

The engine throttle valve is kept open while this test is being made, the engineer simply making a light service reduction to see whether, and how well, the brakes take hold. As soon as he feels them take hold properly, he releases. While making the reduction, the engineer should note the length of time the train pipe exhausts, since by so doing he can judge of the length of the train pipe that is cut into service.

TEMPERATURE TEST.

22. It is well known that the holding power of the brakes varies greatly on different cars, due to defects in the brake system. It is well known, also, that if a brake is applied to a revolving wheel for any length of time, the wheel will become heated; and the longer the brake is held on, or the greater the

retarding force exerted by it, the greater will be the resulting temperature of the wheel. Of course, the brakes on a train are all applied at the same time, so that if they held equally well the wheels would be of a uniform temperature throughout the train, and no information could result from a test of the wheel temperature. It will be found, however, that the wheels heat unequally, some being much hotter and others much cooler than the average. If the brakes on the wheels of average temperature are assumed to be doing their proper share of work, those on the wheels of higher temperature must, for some reason, be doing more than their share, while those on the wheels of lower temperature must be doing less than their share; hence, a test and record of the temperature of the wheels of a train, after the brakes have been applied for some time—as in descending a long grade—will give some very interesting and useful information as to the condition and relative holding power of the brakes on different cars. The record should be such that it will show clearly which brakes require attention, and therefore should contain a statement of the number of each car on which the temperature of the wheels is very much above or below the average, and whether the wheels are too hot or too cold.

23. Locating Defects.—Having, then, a record of the defective brakes, stating the comparative temperatures of the wheels, it remains to locate and remedy the defect that causes the trouble.

If the wheels on a certain car are *too hot*, it indicates either that the brake on that car holds better than the other brakes or else it did not fully release with the others, and, consequently, had been dragging. Hence, the piston travel on that car should be measured to see whether it is too short, and the hand-brake inspected to see whether it is fully released. Also, inspect the pressure retainer to see whether it is working properly, and the brake cylinder to see whether the piston is stuck out, due to a defect in the cylinder or brake rigging. The brake may have been held on, due to a leak from the train pipe into the cylinder past the emergency valve, but this would be at once detected by a blow at the triple exhaust port.

If the wheels are *too cold*, it indicates either that the brake, for some reason, did not hold as well as the others, or did not apply with the others, or else that it released soon after it was set. The brake-piston travel, therefore, should be measured to see whether it is too long—in which case the force exerted by the brake would be considerably less than with the proper piston travel; or whether it is too short—in which case it is possible that the brake piston does not cover the leakage groove, the brake leaking off as a result. Also, the brake may not have applied at all, as the cut-out cock may not have been opened; or else it may have released again, due to leakage in the brake cylinder, auxiliary reservoir, triple valve, or—when the brakes have been released and the retainer is supposed to be holding 15 pounds in the brake cylinder—in the pipe leading to the retaining valve.

On roads where there are long down grades on which the retainers must be used, the wheel-temperature test is especially essential. When the brakes are held on for a considerable length of time, some of the wheels are liable to become very hot, and since the heating takes place at the rim, the wheel is subjected to stresses that are liable to cause it to break.

HANDLING TRAINS.

SERVICE STOPS.

24. General Considerations.—In making a service application of the brakes, the amount of the first reduction will depend somewhat on the length of the train. Whatever the length of the train pipe, the first reduction must be sufficient to cause the brake-cylinder pistons to move out far enough to cover the leakage grooves; otherwise, the brake will not set, and the air that should have been used in setting it will pass out through the leakage groove and be wasted. If too heavy a reduction is made, the slack of the train (if a freight) will run in so quickly that a severe shock will result.

The amount of reduction necessary to cover the leakage grooves can readily be determined when testing the train or when making the first stops. In passenger service, from 5 to 7 pounds is generally sufficient for the first reduction. With a freight train consisting of, or controlled by, ten air cars, a reduction of from 5 to 7 pounds will give good results. When the train contains more than this number of air cars, the reduction must be increased accordingly. For example, a train containing twenty-five air cars will probably require an 8-pound initial reduction, while a train of fifty or sixty air cars may require a 10-pound reduction.

25. The First Reduction.—There are several reasons why a **heavier first reduction** is necessary with a long train than with a short one. Of course, since the volume of air contained in the equalizing reservoir is constant, regardless of the length of the train line, a reduction of chamber *D* pressure (of any given amount) can always be made in practically the same time. The volume of air in the train line, on the other hand, increases directly with its length, so that the longer it is, the more time is required to make a given reduction in the train-pipe pressure. Now, since train-pipe pressure reduces more slowly on a long train than on a short one, there is a greater chance for auxiliary pressure to feed back into the train pipe through the feed groove before it is closed by the triple piston. This reduces auxiliary pressure and has the same effect as though the first reduction had been lighter. Then again, the slower the train-pipe pressure is reduced, the slower will the auxiliary pressure feed into the brake cylinder, and, consequently, the more air will leak out of the leakage groove and past the packing leather.

The amount of the reduction depends, also, on the fit of the equalizing piston packing ring in the brake valve. This ring never makes an air-tight fit, and in some cases considerable air can leak by it. Now, when the train is long, a reduction can be made several seconds sooner in chamber *D* and the equalizing reservoir than in the train pipe; hence, chamber *D* pressure may be less than train-pipe pressure for several seconds during

a service reduction. In consequence of this, air will leak back from the train pipe into chamber *D* and raise chamber *D* pressure, and the longer it takes for the train pipe to reduce, or the more the piston packing-ring leaks, the more will chamber *D* pressure be raised. Thus, what is intended for a 6- or 7-pound train-pipe reduction may result in only a 4- or 5-pound reduction, and in order to get the 6- or 7-pound train-pipe reduction in such a case, a reduction of 8 or 9 pounds may be necessary.

26. Reductions Following.—The amount of the reductions **after the first reduction** depends somewhat on the length of the train pipe and the condition of the brake apparatus. With the apparatus in good condition the reductions should not, as a rule, be more than from 2 to 6 pounds, being small when the train pipe is short, and increasing as the length of the train pipe increases.

Experiment has shown that a brake grips the wheel better, and, consequently, retards the train more, at slow than at fast speeds for the same train-pipe reduction; therefore, the danger of producing shocks is greatest at slow speeds, and the reductions should be made accórdingly. Also, sufficient time must elapse between reductions to allow all of the brakes to set and the slack to equalize throughout the train. If the reductions are made too close together, the effect will be the same as though one heavy reduction had been made. For example, if one 3-pound reduction is followed by another before the train-pipe exhaust ceases, the brakes will set as though a 6-pound reduction had been made. It must be remembered that the graduating valve in the triple valve does not close until the train-pipe exhaust ceases, regardless of when the preliminary exhaust stops, and any reduction made before it closes will prevent that event taking place until auxiliary pressure is reduced an amount equal to the sum of the reductions.

27. Number of Reductions.—The **number of reductions** to be made in a service application depends on circumstances. It is not good practice to wait so long before applying the brakes that a sufficient number of heavy reductions must be made to cause a full application, in order to make the stop

at the proper spot. It is better to make the first reduction at such a distance from the stopping point that a full application of the brakes will not be necessary. The reductions should be moderate and sufficient in number to make not more than a 15-pound train-pipe reduction in bringing the train to a standstill. The engineer then has at his command a reserve braking force that will be of the greatest value in case of emergency while running into a station.

28. Passenger-Train Stops.—An ordinary **station stop** with a passenger train is generally made with one application of the brakes, and in no case should more than two applications be necessary. A 5- or 6-pound reduction should be made at the proper distance from the stopping point, and this should be followed by a sufficient number of 2- or 3-pound reductions to bring the train to rest gradually at the proper point. The brakes should be released just before the train stops, so that the car trucks can right themselves while it is still in motion. If this precaution is not taken, there will be an unpleasant lurch backwards just as the train stops.

Stops on Grades.—In making a **stop on a grade** where the brakes must be held on, it is best to use two applications of the brakes. The first application should be made as though the train were to be stopped a little short of the actual stopping point; then release the brakes (without recharging at all) when two to four car lengths from the stopping point, according to conditions. As soon as the car trucks right themselves, apply the brakes again lightly and leave them on. A light application, such as would be made in a case of this kind, does not tilt the trucks much; consequently, no surge is felt as the train stops. On some roads, all service stops with passenger trains are made with two applications of the brakes, and such practice gives good results.

Overcharging Train Pipe.—In releasing the first application preparatory to making the second, when stopping a train, the brake valve should be thrown to full release and then immediately moved to lap position, as otherwise the train pipe will be **overcharged.** The aim should be to just raise the train-pipe

pressure sufficiently to release the brakes without trying to recharge the auxiliaries any. The feed groove in the triples is small, and if the brake valve is left in release position so long that the train pipe is charged 15 or 20 pounds higher than the auxiliaries, these latter may not have time to equalize with the train pipe before the second application has to be made. Suppose that the train-pipe pressure is 6 or 7 pounds higher than the auxiliary pressure when the second application is about to be made: to set the brake with the first reduction, the engineer must make a 12- or 13-pound reduction—6 or 7 pounds to make the train pipe equal to the auxiliary pressure, and a further reduction of 5 or 6 pounds to apply the brakes. If the engineer makes the ordinary reduction, the brake will not apply, and the train will either run past the stopping point, or else the engineer will have to make an emergency application, which will, when the train is running slowly, cause a very disagreeable lurch. The easiest way to avoid this is not to overcharge the train pipe when releasing the brakes.

Number of Applications.—It is not good practice to make **more than two** applications of the brake in stopping a train. Every time the brakes are applied and released, the amount of air taken into the brake cylinder from the auxiliary is discharged into the atmosphere. This reduces the auxiliary pressure, so that on the second application it equalizes with the brake cylinder at a much lower pressure than on the first, while on the third application it equalizes at a very greatly reduced pressure. For example, if a brake is adjusted so that it will equalize with the auxiliary at about 50 pounds on the first application, it will equalize at about 30 pounds on the second, 20 pounds on the third, and at only about 10 or 12 pounds on the fourth application. It will thus be seen that the power of the brake falls away very rapidly with each application; hence, the advisability of making but two applications at the most.

As already stated, two applications are advisable when making a stop on a grade. It will be found advisable, also, to make two applications whenever a close accurate stop is to be made, such as at water tanks or coal chutes. In each instance

the stop should be made according to the instructions just given for a stop on a grade, and the brakes should be held on until the water or coal has been taken.

Holding Brakes On.—When the brakes are to be **held on** for any length of time, and the engineer's valve is of the D-8 type, it will be necessary to stop the pump when main-reservoir pressure is obtained; otherwise, it would continue to work and overcharge the main reservoir. This in turn would overcharge the train pipe as soon as the brake valve was placed in release or running position, skidded wheels would probably result, and any old or weak hose would be very likely to burst.

Stopping by Means of Tail Hose.—When the train is to be backed some distance and stopped by one of the train hands by means of the **tail hose,** the engineer should carry his brake valve in running position until he is given a signal or feels the first application, when he should immediately place the brake valve on lap. During the run backwards the brake valve must, of course, be carried in running position to supply any train-line leaks, but it should be lapped in time so that the man making the stop will not be hampered and will have complete control of the train, since he is the man that is responsible for the way the stop is made.

29. Part-Air Freight Trains.—The amount of free slack in a part-air train is principally what makes such a train so difficult to handle without producing shocks, and, every time the speed of the train is altered, this slack must be taken care of. As already remarked, this free slack must either be gathered in or run out every time the speed of the train is changed, and the more quickly this is accomplished, the greater will be the resulting shock. Also, as remarked in Art. **3,** the extent of the shock will depend on the number and position of the loaded cars in the non-air section, and on the extent to which the air section resists the blow as the slack is bunched or run out. If there is a sufficient number of air cars to hold well and the loads are at the rear end of the train, the shock will be severe if the slack is bunched quickly; consequently, a train should always be bunched or stretched gradually.

In making a service stop with a part-air train, close the throttle at a sufficient distance from the stopping point, and let the train drift for a short distance, or until it has bunched fairly well. A reduction just sufficient to close the leakage grooves should then be made, and ample time allowed for any slack to run in before a second reduction is made. The second and succeeding reductions should be sufficiently light and numerous to bring the train smoothly and gradually to rest at the proper point, care being taken that one reduction is not made until after the train-pipe exhaust of the previous one has ceased.

As a rule, the brakes should be held on until the train has come to rest, as otherwise a shock tending to tear the train in two will be caused, due to the slack running out. They should be released immediately after stopping, however, so that the brakes on the air cars may not be rigidly set when the non-air cars run back—as they will do when the spring slack eases up.

Use of Hand-Brakes.—It should not be necessary to use hand-brakes to assist the air brakes in making a service stop, but in case this has to be done, the brakes immediately back of the air cars should be used, and not those at the rear end of the train. When hand-brakes are used, they should be released before the air brakes, as otherwise a break-in-two is liable to occur. In backing a part-air train out of a siding, however, a few hand-brakes should be applied at the rear end of the train before the air brakes are applied, so that the slack of the non-air section will not run out violently when the air brakes are applied to stop the train.

Water-Tank and Coal-Chute Stops.—It is a very difficult matter to apply or release the brakes of either a part-air or an all-air freight train at slow speeds, without a more or less severe shock resulting; hence, the safest way to make a close, accurate stop with a freight train is to stop short of the tank or chute, cut the engine off, take coal or water, and then couple up to the train again.

A good way to make an accurate stop with a "lone" engine is to apply the brake in such a way that it will tend to stop 3 or 4 feet short; then, without releasing, use

a little steam just before it ceases to move, and the instant the throttle is closed the engine will stop.

30. All-Air Freight Trains.—Although in making stops with an all-air train the engineer does not have to deal with a lot of free slack, as in the case of a part-air train, yet if the train is very long, he will have trouble with slack, since the head-end brakes apply and release sooner than the rear ones, in consequence of which, the slack plays in or out when the first reduction is made or the brakes are released. Also, as stated in Arts. 4 and 5, uneven distribution of load and unequal travel of the brake pistons complicate matters so that good judgment and skill must be exercised in handling such a train or else rough treatment of freight is sure to follow. Both the first and succeeding reductions must be heavier (according to the length of the train) than for short freight or for passenger trains (see Arts. 28 and 29). The first should be sufficient to cover all of the leakage grooves, and no succeeding reduction should be made before the train-pipe exhaust, due to the previous one, has ceased. After one or two applications of the brake, the engineer can judge pretty closely what reductions to make in order to handle the train smoothly.

In making a service stop with a long all-air freight train, the first reduction should be made at a sufficient distance from the stopping point, and once the brakes are applied they should be held on until the train has come to a standstill. It is almost impossible to release the brakes on a very long train at slow speed without breaking the train in two, unless the retainers are used on the engine. Some roads are equipping their engines with retainers or other appliances that are intended to prevent the slack from running out violently in case it is necessary to release at slow speeds.

If necessary to release brakes while the train is moving, sufficient excess pressure should be pumped up to insure the prompt release of the brakes, and the engine retainers, if the engine is supplied with them, should be cut into service. Care should always be taken not to work steam until all brakes on the train have released, and even then the throttle should be

opened cautiously; for, if steam is worked before the rear-end brakes have released, the train is tolerably certain to be torn in two. After releasing the brakes, one second for each car in the train should be allowed before steam is used, so that sufficient time will be allowed for all brakes to release and the drawbar springs to adjust themselves.

EMERGENCY STOPS.

31. Brake Stops.—In cases of actual emergency, the brake valve should be thrown to full emergency position **and left there,** and sand should be used. Of course, it is possible to get the emergency action of the brakes without losing all the train-pipe air, but it is not good policy to try to do so in times of pressing danger. In the first place, if several cars with plain triples or with brakes cut out happen to be placed together, only the brakes ahead of such cars will go into quick action, while the ones back of them will set with a partial-service application only. If the valve is left in emergency position, a full application will be had on the cars back of, and full emergency on those ahead of, the cars with plain triples. Another possibility is that during the excitement the engineer may, in trying to bring the valve back to lap, move it to running position, thus releasing the brakes; or, if the valve is moved to lap too quickly, the surge of the air in the train pipe may kick off the forward brakes.

Everything considered, the safest plan is to move the brake valve to emergency position and leave it there, and not try to save air in the hope that if the train can be stopped in time the brakes can be released and the train backed up and thus avoid the danger. No matter what the position of the brake valve or the kind of train—whether all-air or part-air—in case of emergency, the brake valve should be moved to emergency position. It makes no difference whether the brakes have been applied in a partial, or even a full, service application—the handle should be moved to emergency just the same. In the former case, a full-emergency application may not be obtained, but a partial emergency may; and certainly a full-service

application would be. In the latter case, if all the brakes were set full, no advantage would be gained, but if any of the brakes had not equalized with their auxiliary, or if some of the brakes had partially or wholly leaked off, the reduction would cause them to equalize with their auxiliaries, thus making them hold better.

32. Reversing the Engine.—No matter how poor the driver- and tender-brakes are, if they are applied, the engine should **never be reversed** with the expectation of making a shorter stop than could be made with the brakes alone; reversing the engine under such conditions may cause the brake to lock and slide the drivers, in which case the retarding power of the engine is practically lost. It was proved by actual trial in the Galton-Westinghouse tests in England, and, later, in tests made by Mr. Thomas, Jr., Assistant General Manager of the N. C. & St. L. R. R., that a stop cannot be made in as short a distance with the driver brakes set and the engine reversed as when the brakes alone are used.

33. Accidental Emergency Stops.—Under this head are supposed to be included all emergency stops other than those purposely made by the engineer. Whenever the brakes apply suddenly without his aid, he should immediately lap the brake valve and leave it in that position, so as to bring the train to a standstill as soon as possible and save main-reservoir pressure for releasing brakes when the proper time comes for so doing. A sudden, unexpected application of the brakes may be caused by a conductor's valve being opened, by a burst hose, or by the train parting.

RUNNING.

POSITION OF BRAKE VALVE.

34. The brake valve should always be carried **in running position** while the brakes are off, since this is the only position in which excess pressure can be carried, and train-pipe leaks supplied by air from the main reservoir. In speaking of

excess pressure, it is meant that there is an excess of pressure in the main reservoir over that in the train pipe; that is, when main-reservoir pressure exceeds train-pipe pressure by a certain amount, *that* amount is called the excess pressure. The excess pressure, therefore, is carried in the main reservoir, and it is very important that it be carried and maintained at all times while the train is running. A sufficient excess should be carried so that when it is turned into the train pipe to release the brakes, it will do so promptly and also recharge the auxiliaries promptly.

The brake valve should not habitually be carried in release position; in fact, ordinarily, it should not be carried there at all. It should simply be moved to, and left in, that position until brakes have been released, when it should at once be moved to running position.

If an F-6 brake valve is left in release position too long, the train pipe will equalize with the main reservoir at 90 pounds pressure. If the valve is then moved to running position, the feed-valve will be held closed until train-pipe pressure has been reduced 20 pounds, or from 90 to 70 pounds. In case the train pipe has been overcharged, it is best to make a number of light applications and releases to reduce the train-pipe pressure to 70 pounds.

If a D-8 valve is left in lap position until the main reservoir is overcharged, the train pipe will be overcharged as soon as the valve is moved to running position, but the regular amount of excess pressure will still be carried. If the train pipe is so badly overcharged that it is advisable to reduce it, apply lightly and release a few times, as before.

SETTING OUT A CAR.

35. In **setting out** a car at a way station, first of all release the brakes; then close the angle cock on each side of the hose that is to be parted; then part the hose by hand, and hang up properly in the dummy couplings the hose of the car that is to be set out. Before the car is left in the side track, the air brake should first be released and then the hand-brake applied

(if necessary) to hold the car. The air brake should never be depended on to hold one or more cars on a grade for any length of time when not connected to the engine, since the brake may leak off and allow the cars to escape down the grade uncontrolled. In case cars must be left standing on a grade, always release the air brakes and apply the hand-brakes.

PICKING UP CARS.

36. When the engine is backed up to a number of cars that are to be switched or **picked up,** the train pipe and auxiliaries on which cars may be empty, it is well to apply and release the engine brakes a couple of times without recharging the auxiliary, and then place the brake valve on lap before the tender angle cock is opened. The auxiliary pressures on engine and tender will then be so low that if the engine brake *does* set in full when the angle cock is opened, the auxiliary and brake cylinders will equalize at such a low pressure that the main-reservoir pressure can very readily release them, and thus time will be saved, as the cars can be charged while they are being moved.

In coupling up a car or cars that have been picked up, and which may not be fully charged, the following precautions should be observed: First, be sure that the rear angle cock on the rear car is closed; then, after coupling the hose, open the angle cock on the car that was picked up, and then the one on the charged section of the train, opening the latter cock slowly so that pressure will not be fed into the undercharged car faster than it is supplied to the train pipe from the main reservoir. By taking this precaution, both time and air will be saved.

HOSE BURSTING.

37. As already mentioned, in the event of a **hose bursting,** the engineer should immediately lap the brake valve, and, as soon as the train stops, send out flags. The hose should be replaced by a new one (if at hand) or by the extra hose on the last car of the train, and the brakes then tested to see whether

they operate properly. If unsafe to replace the hose and test the train at the time, the angle cock immediately in front of the burst hose should be closed; the brakes back of it should then be bled off, and the train moved to a safe place, where the hose can be replaced and the brakes tested.

To Locate a Burst Hose.—If the leak is not too large, the brake valve should be left in partial-running position; the leak can then be located by the sound made by the escaping air, while at the same time main-reservoir pressure can be maintained. With a large leak, however, it would be impossible to open the valve wide enough to make a sound and still maintain the main-reservoir pressure; consequently, the brake valve should be moved periodically from lap to full release and back again. This will produce an intermittent sound by means of which the leak can be located.

BLEEDING BRAKES OFF.

38. There are two methods by which a triple valve can be made to release a brake. One is to increase the train-pipe pressure above that in the auxiliary—the other to reduce the auxiliary pressure below that in the train pipe. The first is the usual way—the second method is the one employed to **bleed off** a brake. To do this, the release valve, or bleed cock as it is often called, should be held open until air escapes from the triple exhaust, when it should immediately be closed. The blow at the exhaust indicates that the triple has moved to release position, and any further reduction of auxiliary pressure is not only a loss of air, but also causes a reduction in the train-pipe pressure, which in some cases may cause other brakes to apply.

BREAKING-IN-TWO OF TRAIN.

39. In case an all-air train should **break in two,** the brake valve should be lapped at once and the engine throttle closed, so as to bring the front section to a standstill as soon as possible. With such a train, the engineer should not attempt to keep the head end out of the way of the rear end, for the reason

that they are pretty sure to come together in any event; and the less the two sections separate, the less damage will be done when they come together. Flags should be whistled out, and as soon as the sections come to a standstill, the last angle cock of the front section should be closed and the brakes on that section released. As soon as the signal is given, the front section should be backed up and coupled to the rear section, and the brakes on the whole train released. A test should then be made to see whether the brakes are working properly.

In the event of a part-air train breaking in two, the course to pursue will depend on whether the break occurs in the air section, or back of it. If it occurs in the air section, pursue the same course as with an all-air train; if it occurs in the non-air section, the brakes, of course, will not set on the air section, and the engineer should endeavor to keep the head section out of the way of the rear section until the latter can be brought to a standstill.

HANDLING TRAINS ON LONG DOWN GRADES.

40. The manner in which the braking should be done on a long down grade depends, to a considerable extent, on local conditions, which may differ widely on different hills; consequently, no rule can be given that will cover all conditions. In order to give instructions for braking on any particular hill, the location of the easy and heavy parts of the grade should be definitely known; hence, instructions are usually issued by the companies, covering the conditions in each case.

In the absence of specific instructions, however, the following will serve as a guide: The pump should be run faster than usual while on the grade, so as to recharge the main reservoir promptly when necessary. Turn the retainer handles up just before the descent is begun, and make a moderately heavy reduction while the speed of the train is slow. It will be remembered that a given reduction will cause the brakes to hold better at slow, than at high, speed; hence, much better control of the train can be maintained, and air saved, by making the first reduction before the train has gained much headway. Good judgment should be used in making the

succeeding reductions, and they should be sufficient in number and amount to maintain the speed of the train well within safe limits.

When possible, curves and easy parts of the grade should be selected on which to release the brakes and recharge the auxiliaries; also, the last reduction before releasing should be heavier than the others, so as to slow down the speed considerably before releasing, since it not only will take a little longer for the brake-cylinder pressure to reduce down to 15 pounds, but the pressure in the brake cylinder will have a greater retarding effect at the slower speed. The auxiliaries should be fully charged just before the steep parts of the grade are reached, so as to have sufficient braking power to hold the speed within bounds while descending. Safety should, of course, be the first consideration, and, in general, the best results will be obtained by a slow speed and the use of retainers while on the grade.

QUICK ACTION DURING SERVICE REDUCTION.

41. If, when making a service reduction, the brakes set quick action, the trouble may be: (1) a broken pin in the graduating valve of the triple; (2) the graduating valve badly gummed up; (3) the triple piston gummed up or frozen, so that it will not respond to an ordinary train-pipe reduction; or, (4) if the train is short, a broken graduating spring *22* in the triple. In sections 3 to 6 of Art. **28**, Part 2, it was explained how these defects cause the brake to apply quick action.

LOCATING DEFECTIVE TRIPLE.

42. Quick action during a service reduction is due to one of the triples, for some reason, not operating in service position, but only in emergency position, thus causing the others to fly on also. If the trouble is due to a sticky triple, or to a broken or gummed-up graduating valve, it may be located as follows: Make a light service reduction and, since all brakes but the defective one will apply, look for a brake that has not set. This, when found, may be cut out at once and the brakes again tested, to see if the brake cut out is the one that has been

causing the trouble. Another method is to make a light reduction and, when a brake is found that has not applied, make a second or even a third reduction, if necessary, while some one watches the brake to see if it goes on quick action only; if so, it should be cut out. Should the trouble be due to a weak or broken graduating spring *22*, the triple will move to emergency position when a light reduction is made, and thus cause all of the brakes to fly on. Generally, a triple with a broken graduating spring is rather hard to locate. To do so, the brakes may be watched to see which goes on quick action first; or an angle cock in the middle of the train may be closed to see on which half the defective triple is located, this being repeated with the portion of the train containing the defective triple until but a few cars have to be watched. These can either be cut out one at a time, or else they can be watched to see which piston moves out first. When located, the defective triple should be cut out.

BRAKES STUCK ON.

43. If it is found that the brakes cannot be released by placing the brake valve in full-release position, it should be placed on lap to obtain excess pressure, and then thrown into full release. The brakes on a long train with quick-action triples are especially liable to stick after an emergency application, on account of the auxiliary and brake cylinder equalizing at a higher pressure than usual. On a very long train the rear brakes are liable to stick after a very light application, because the train-pipe pressure cannot be raised enough to move the sticky triple; with a heavier reduction this triple will very likely release promptly.

USE OF SAND.

44. It is well known that by the proper use of sand the wheels may be made to grip the rails much better, thus lessening the danger of the wheels being flattened from sliding. On the other hand, if the sand is not properly used and the wheels begin to slide, the flat spots formed will be worse than if no sand were used.

When necessary to use sand in making a stop, the rails under the entire train should be sanded by the time the first application is made, or at least before the brakes have applied very hard, and the sand should be used continuously until the train comes to a standstill. Sand should never be used after the wheels have begun to slide, since it will not start them turning again, but will simply increase the wear on the wheel and thus make the resulting flat spot larger than it otherwise would be. In the event of the wheels sliding, the brakes should be released, if practicable, and the rails sanded; after which the brakes may be applied again, but the rails should be continuously sanded until the stop is made. Whenever the rails are bad, sand should be used in applying the brakes, to avoid skidding the wheels. It is bad practice to attempt making a stop without using sand and then, after the brakes have been fully applied and it looks as though the train would not stop soon enough, to drop sand on the rails. Some of the wheels may be sliding at the time, and the sand will thus be the cause of some very bad spots.

WHEELS SLIDING.

45. When the brakes are applied, there are two forces acting on the wheels: one, the force exerted by the brake, which tends to prevent the wheel from turning, and thus tends to cause it to slide over the rail like a sled runner; the other, the force exerted between the wheel and the rail, which resists this tendency to slide, and thus tends to keep the wheel turning. As long as the latter force is greater than the former, the wheel will continue to revolve; but if, for any reason, the force exerted by the brake is the greater, the wheel will **slide**. It will thus be seen that a wheel may be made to slide either by reducing the adhesion between the wheel and the rail (as when the rails are greasy), or by increasing the force exerted by the brake above a certain amount.

Apart from the matter of slippery rails, therefore, the wheels may be slid: if the piston travel is too short, whether due to its adjustment, to the hand-brake being partially set, or otherwise; if the leverage is too great; if the brake fails to release after

a heavy application in making a stop; if a heavy reduction is made when the train is moving slowly; or if the auxiliaries are overcharged and allowed to equalize with the brake cylinders. Some types of driver brakes may lock and skid the wheels if the piston travel is allowed to become too long.

USE OF CONDUCTOR'S VALVE.

46. In passenger service, each car is provided with a valve called the conductor's valve (see Fig. 1, Part 1), by means of which the brakes can be applied from the cars. This valve is connected to the train pipe by means of a branch pipe, and when the valve is open it makes a direct passage from the train pipe to the atmosphere. The conductor's valve is intended to be used only in cases of emergency, when it is necessary to stop the train as soon as possible. In such an event it should be held open until the train comes to a stop, for if it should be closed while the engineer's brake valve is in running position, the brakes will be released again.

DOUBLE-HEADING.

47. In **double-heading,** it is the duty of the leading engineer to handle the brakes, and the cut-out cock in the train line under the brake valve of the "following" engine should be closed, so as to give him absolute control. After closing the cut-out cock, the engineer of the following engine should place his brake valve in running position and keep his pump operating so as to maintain the full main-reservoir pressure in case the leading engineer desires assistance in releasing brakes. In that event, the following engineer should open the cut-out cock under his brake valve and place his valve in full release, but the brake valve should be moved to running position, and the cut-out cock closed again as soon as the brakes release, or the control of the train will be taken away from the leading engineer.

If the following engine is not supplied with a cut-out cock, the brake valve should be carried on lap instead of in running position; a blow may then occur at the train-pipe exhaust when brakes are released. When the leading engineer places

his brake valve in release position, he increases the train-pipe pressure above that in chamber *D* of the following engineer's brake valve, and the equalizing piston of that valve may be raised, and open the train-pipe exhaust. In this event, the brake valve should be placed in full release until the blow ceases, and then be returned to lap.

PISTON TRAVEL AND ITS ADJUSTMENT.

LONG AND SHORT TRAVEL.

48. The subject of **piston travel** and its **adjustment** is an important one, and should be thoroughly understood, since not only the efficiency of the brake, but also the smoothness with which a train can be handled, depends to a great extent on the proper adjustment of the brake-piston travel.

The auxiliary reservoir used with any brake cylinder is of such a size that if charged to 70 pounds it will equalize with the brake cylinder at 50 pounds, if the travel of the brake piston is adjusted to 8 inches. If the piston travel is less than 8 inches, the auxiliary and brake cylinder will equalize at a higher pressure than 50 pounds, while if the travel is more than 8 inches, they will equalize at a lower pressure. When a train-pipe reduction is made, air passes from the auxiliary (into the brake cylinder) until the pressures in auxiliary and train pipe are about equal. Thus, for a given train-pipe reduction, the same amount of air is discharged into the brake cylinder, regardless of the length of the piston travel. That is to say, if a 7-pound reduction were made, the same amount of air would pass into a brake cylinder having a 5-inch piston travel as would pass if the travel were 8 inches. With the 5-inch travel, however, the air would have to occupy less space than with the 8-inch travel; hence, it can readily be seen that the brake with the short travel will develop the greater pressure.

EQUALIZATION TESTS.

49. The following table gives the results of a number of **tests** made with a freight equipment, each pressure given

being the average of several trials with each piston travel. It shows the pressure obtained in the brake cylinder for different piston travels in both service and emergency applications of the brake.

BRAKE-CYLINDER PRESSURES.

Service Reduction From 70 Pounds Train Pipe.	Piston Travel.							
	4″	5″	6″	7″	8″	9″	10″	11″
7	25	23	17½	13	10½	8		
10	49	43	34	29	23½	19½	17	14
13	57	56	44	37½	33	29	24	20
16	57	56	54	47½	41½	35	29	24
19	57	56	54	51	47	40	36½	32
22	57	56	54	51	50	47½	44	39
25	57	56	54	51	50	47½	47	45
Emergency reduction	62	61	59½	58½	57½	56½	55½	55

Explanation of Table.—The first column on the left gives the reduction in train-pipe pressure; the second column gives the brake-cylinder pressure resulting from the corresponding reduction in column 1, when the brake-piston travel is only 4 inches; the third column gives the resulting brake-cylinder pressure when the piston travel is 5 inches, and so on for the other columns. For example, a train-pipe reduction of 7 pounds will result in a brake-cylinder pressure of 25 pounds with a 4-inch travel, or 8 pounds with a 9-inch travel; a 10-pound reduction will result in 43 pounds brake-cylinder pressure with a 5-inch travel, and only 14 pounds with an 11-inch travel.

By studying the table carefully, some very useful information may be derived. It will be found that short-travel brakes equalize quicker, and with a less reduction, and also exert a greater pressure than do long-travel brakes. For instance, a 13-pound reduction will cause all brakes with 4-inch travel to equalize at 57 pounds pressure, and with 5-inch ones to equalize at 56 pounds; while a 25-pound reduction is necessary to set a brake full with a 10- or 11-inch travel, and then they equalize at only 47 pounds and 45 pounds, respectively.

It will be seen, also, that if three brakes, with, say, 4-, 8-, and 11-inch travel, respectively, were in the same train, the retarding force exerted by each would vary greatly at each reduction. For instance, a 7-pound reduction would cause the first to develop 25 pounds pressure per square inch; the second, 10½ pounds; while the pressure in the cylinder having the 11-inch travel would not be sufficient to move the piston out the full stroke. Now, if the brake cylinders were of 10-inch diameter, a pressure of 25 pounds per square inch in the short-travel brake would develop a total force of 1,963 pounds; 10½ pounds per square inch in the medium-travel brake would develop a total force of 825 pounds; while the long-travel brake would hardly develop sufficient power to force the piston to its full stroke. Thus, of these three brakes, with a 7-pound reduction, the holding power of the first would be nearly 2½ times as great as that of the second, while the third would be altogether ineffective. It is this difference in holding power, due to unequal piston travel, that makes it so difficult to handle freight trains smoothly.

To sum up briefly, the table shows: (1) that the short-travel brakes in a train hold harder at each reduction than the long-travel ones; (2) that they equalize with their brake cylinders with a less train-pipe reduction, hence equalizing sooner than the long-travel brakes; (3) that they equalize at a higher pressure; (4) that since they equalize at higher pressure, they must release later than the brakes with long travel after a full reduction.

When the train-pipe pressure is increased to release the brakes, it will release those having a 10-inch travel at 47 pounds pressure, but it must be increased 9 pounds more, or to 56 pounds, to release those having a 5-inch travel. As soon as the first brakes release, their auxiliaries commence recharging, thus making train-pipe pressure increase more slowly than it otherwise would, and delaying the release of the short-travel brakes. If sufficient excess pressure to release the short-travel brakes is not carried, the wheels will probably be slid while the brakes are being pumped off, and bad spots will result. Besides this, the train is subjected to severe wrenches tending

to break it in two, on account of the long-travel brakes releasing before the others. However, if the travel is adjusted within certain limits, all brakes will start releasing at about the same time, the tendency being for the long-travel brakes to release first. If the travel were uniform throughout the train, the tendency would be for the brakes nearest the engine to release first, since train-pipe pressure is increased there first. If none of the brakes have been set in full, they should begin releasing at about the same instant (regardless of the difference in piston travel); this is due to the fact that until a brake equalizes, its auxiliary pressure is practically equal to train-pipe pressure.

The last row of figures in the table shows that the resulting brake-cylinder pressure obtained in an emergency application of the brakes decreases as the piston travel is increased.

RUNNING TRAVEL.

50. The piston travel is greater by from 1 to 2 inches when the train is running than when standing still, on account of (1) loose journal brasses, allowing the wheels to move; (2) loose boxes in pedestals; (3) loose truck kingbolts, allowing the trucks to pull together; and (4) the "spring" in the brake beams, levers, or connections. The amount that the brake piston travels when the brakes are applied and the train is in motion is called the **running travel.** Brake beams are sometimes so hung that the brake shoes pull down lower on the wheels when the brakes are applied, and since in that case the shoes travel farther to touch the wheels, the piston travel is increased.

Also, the travel is generally greater when the car is loaded than when unloaded. If the brake beams are hung to the side sills of a car or to the bolster, they will be lowered (consequently increasing the travel) when the car is *loaded*, and raised again (shortening the travel) when it is *unloaded.* To avoid this bad effect, some roads hang the brake beams to such a part of the truck that the center of the brake shoes is always the same distance from the rails, regardless of whether the car is loaded or not. The method gives very good results.

THE PROPER PISTON TRAVEL.

51. The different parts of the air-brake apparatus are so designed and constructed that the proper brake-shoe pressure will be obtained—in a full-service application of the brakes—with a pressure of 50 pounds per square inch in the brake cylinder. The brake, therefore, would be safer and more efficient if the piston travel were always to remain such as to just give 50 pounds pressure in the brake cylinder—i. e. between 7 and 8 inches—but as the brake shoes wear quite rapidly, the travel is bound to increase unless, as such wear proceeds, this travel is automatically adjusted by means of a **slack adjuster.** Automatic slack adjusters not being in general use, it has been customary on most roads to take up the shoe slack on passenger cars and tenders until the piston travel is about 6 inches; the brake is then allowed to run until the wear of the brake shoe increases the travel to 8 inches, when the slack is again taken up.

The limits between which the piston travel is allowed to vary are, on most roads, as follows: For passenger-car and tender brakes, between 6 and 8 inches; for standard freight cars, between 5 and 9 inches. On the engine, one auxiliary reservoir supplies air for the two driver-brake cylinders; consequently, a 1-inch travel of each of the driver-brake pistons is equivalent to a 2-inch travel of a car-brake piston. On some roads the driver-brake piston travel is allowed to vary between $\frac{1}{3}$ and $\frac{2}{3}$ of the full stroke of the piston. The better practice, however, is to use an air gauge on the brake cylinder and adjust and maintain the travel so that 50 pounds per square inch will be obtained in the brake cylinder on a full application of the brakes.

MEASURING THE PISTON TRAVEL.

52. To **measure** the brake-piston travel, force the push rod—if one is used—into the sleeve until it bottoms on the brake piston, and the latter is forced against the cylinder head; then make a mark on the end of the cylinder and measure the distance between the mark and the center of the lever pin in the push rod. Apply the brake in full, and again measure

from the same mark on the cylinder to the center of the lever pin; the difference in the measurements will be the amount that the piston travels.

If it is desired to measure the piston travel on an uncharged car, proceed as before, only in this case the brakes will have to be set by hand; if necessary, use a piece of wood or a bar of iron as a lever to set them up tight. This method can only be used on cars on which the air brakes and hand-brakes move the piston lever in the same direction in applying the brake.

ADJUSTING BRAKES.

53. Adjusting Car Brakes.—In regulating the piston travel of a car or tender brake (*Hodge* system), the slack of the brake shoes is taken up by means of the truck dead lever. This is accomplished by moving this lever so as to reduce the shoe clearance, since the smaller this clearance, the less the piston will have to move to draw the shoes up against the wheels. The top of the dead lever is held by a pin that runs through a guide and the lever, the top of the lever traveling between the sides of the guide. The position of the lever in the guide can be changed by removing the pin and moving the lever until it connects with one of the many holes in the guide. Extra holes are sometimes put in other connections of the brake rigging so that, if necessary, part of the slack may be taken up there. For instance, if sufficient slack cannot be taken up at the truck dead lever, one or two holes should be taken up in the other connection and the travel then adjusted by means of the truck dead lever.

On most freight cars, both the hand-brake and the air brake move the levers in the same direction in applying brakes; hence they are said to work together. On nearly all passenger, and a few freight, cars, however, the hand-brake and the air brake move the levers in opposite directions; if, then, the hand-brake chain is wound up a little, the piston travel will shorten a corresponding amount when the air brake is next applied. When the hand-brake and the air brake work together, winding up the brake chain does not shorten the piston travel.

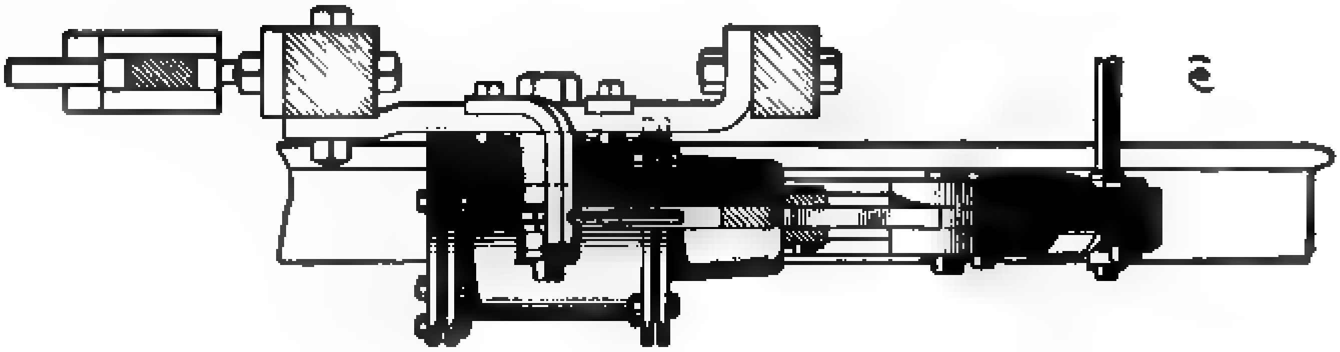


FIG. 1

The practice of shortening the piston travel by winding the hand-brake up a little, instead of moving the dead lever, is a bad one, and is decidedly dangerous. If the brake dog on the hand-brake should work out of the ratchet, the slack would run out; also the extra strain on the brake chain tends to break it. If too much chain is wound up, the travel may be shortened so much that the piston will not cover the leakage grooves and the brake will not apply. Then, again, if the air brake tends to turn the hand-brake wheel in a direction opposite to that which it must be turned by hand to set the brakes, there is always danger of a person being hurt should he try to turn the hand-brake when the engineer happens to be setting the air brakes.

54. Cam Driver-Brakes.—In Fig. 1 are shown two views of the *push-down* type of **cam driver-brake,** (*a*) being a side view, and (*b*) an end view. As air is admitted into the brake cylinder *C*, the piston and, consequently, the crosshead *h* are forced downwards, thus causing the cams to roll on each other and move the cam-screw pins outwards, pressing the shoes against the wheels.

The distance between the link pin *a* and the cam-screw pin *b* can be changed by means of the cam-screw *c*, and it is by means of this screw that the piston travel is adjusted. To shorten the travel, the distance between the pins is lengthened.

In taking up the slack of the brake shoes, care must be exercised to lengthen both cam-screws the same amount, so that the point of contact of the cams will be in line with the center of the brake cylinder. Sufficient shoe clearance should be allowed.

55. Outside Equalized Driver Brake.—In Fig. 2 are given two views of the American outside **equalized driver brake** as generally used at the present time on engines having three or more pairs of drivers, (*a*) being a side view and (*b*) a plan view. In this type of brake the piston is connected to the brake rod *R* by a bell-crank lever *L* that turns on the pin *P*, so that when the brake piston is forced outwards, the brake rod *R* is drawn backwards and applies the brake shoes to the wheels.

A slack adjuster *T* (popularly spoken of as a *turnbuckle*) is provided for the purpose of taking up the slack as the brake

(a)
FIG. 2.

shoes wear. This is accomplished by loosening the locknut *s* on the screw bolt, and turning the bolt in such a way as to pull the brake rod *R* backwards, thus moving the brake shoes up nearer to the wheels. The pipe *p* leads from the brake cylinder to the triple valve.

BRAKE GEAR.

LEVERS AND LEVERAGE.

56. The foundation brake gear on engines, tenders, and cars consists simply of a system of levers connected together by rods; and it is by means of these levers that the force developed in the brake cylinder is transmitted and applied to the wheels.

It is desirable, therefore, to be able to calculate the braking power that a system of levers is capable of exerting, and to do this the different classes of levers must be studied.

SIMPLE LEVERS.

57. The Straight Lever.—A **lever** is any bar that is capable of being turned about a fixed axis or pivot, called the **fulcrum**, as in Figs. 3, 4, and 5. In these figures, *W*, the object to be lifted, is called the *weight;* the force *P*, employed to lift the weight, is called the *power;* and the point *F*, round which the lever turns, is called the *fulcrum*. That part of the lever *Fb* between the fulcrum and the weight is called the *weight arm* of the lever, while the part *Fc* between the fulcrum and the power is called the *power arm.*

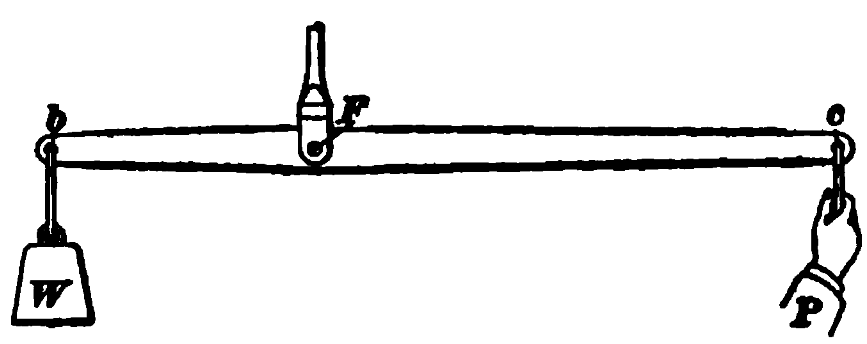


FIG. 3.

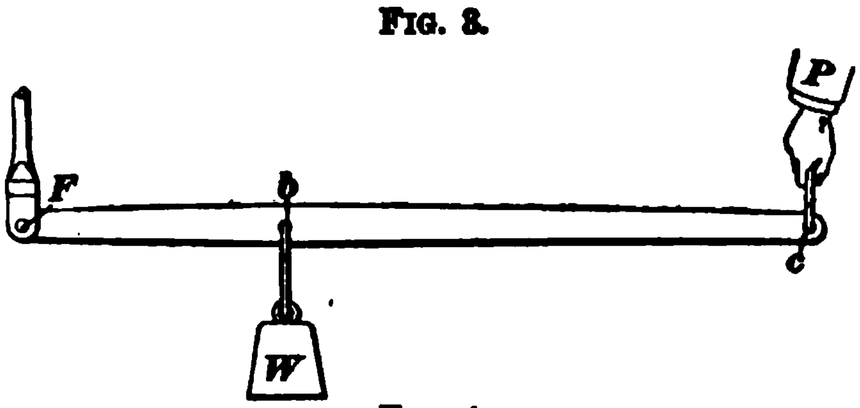


FIG. 4.

The fulcrum *F*, it is to be remembered, is stationary, and the lever is perfectly free to turn on it. Now, if the weight *W* is

great enough, it will cause the lever to turn or rotate about the point F against the action of the power P; if, on the other hand, the power is great enough, it will cause the lever to rotate about F against the action of the weight W. In other words, it will raise the weight. When the power P is just sufficient to balance the weight W, and the lever, therefore, does not move, it will be found that:

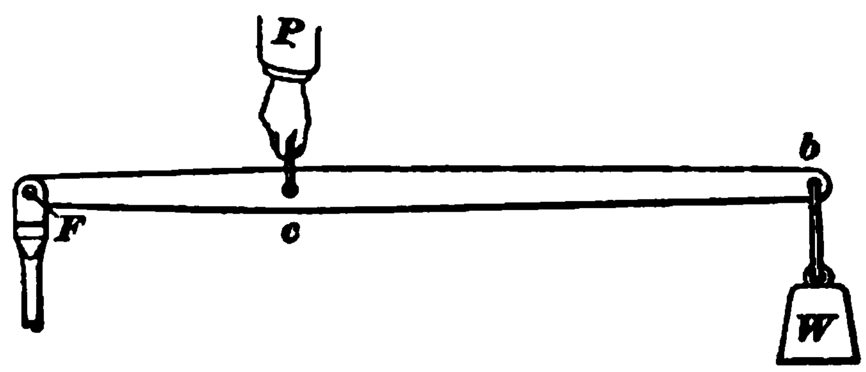


FIG. 5.

Rule I.—*The power multiplied by the power arm is equal to the weight multiplied by the weight arm.*

Thus, in Fig. 5, the power P, multiplied by the distance Fc, will just equal the weight W multiplied by the distance Fb.

Or, expressing this in symbolic form,

$$P \times Fc = W \times Fb.$$

From this it can readily be shown, that

$$P = \frac{W \times Fb}{Fc}; \qquad (1)$$

$$W = \frac{P \times Fc}{Fb}; \qquad (2)$$

$$Fc = \frac{W \times Fb}{P}; \qquad (3)$$

$$Fb = \frac{P \times Fc}{W}; \qquad (4)$$

where P stands for the force or power applied, W for the weight, Fc for the length of the power arm, and Fb for the length of the weight arm.

It will be seen that only four quantities enter into these equations, as the above expressions are called, and if any three of these quantities are known, the other can be determined by means of one of the equations. The use of the equations, or formulas, is illustrated in the following examples:

EXAMPLE 1.—If the power arm of the lever is 20 inches long and the weight arm 10 inches long, what power must be applied to just balance a weight of 1,000 pounds?

SOLUTION.—In this example we see that $Fc = 20$, $Fb = 10$, $W = 1{,}000$, and P is to be found; therefore, substituting these values in formula (1), we find that

$$P = \frac{W \times Fb}{Fc} = \frac{1{,}000 \times 10}{20} = 500 \text{ pounds. Ans.}$$

EXAMPLE 2.—If a power of 1,000 pounds is applied to the lever of example 1, how many pounds weight will it balance?

SOLUTION.—In this example, $Fc = 20$, $Fb = 10$, and $P = 1{,}000$; W is to be determined, hence equation (2) will be used. From this,

$$W = \frac{P \times Fc}{Fb} = \frac{1{,}000 \times 20}{10} = 2{,}000 \text{ pounds. Ans.}$$

EXAMPLE 3.—Suppose a force of 1,600 pounds at P has either to support a weight or exert a force of 3,200 pounds at W. How long must the power arm be, the weight arm being 10 inches?

SOLUTION.—In this case, $P = 1{,}600$, $W = 3{,}200$, and $Fb = 10$. Therefore,

$$Fc = \frac{W \times Fb}{P} = \frac{3{,}200 \times 10}{1{,}600} = 20 \text{ inches. Ans.}$$

EXAMPLE 4.—If, in example 3, the power arm were 10 inches long, what length would the weight arm have to be?

SOLUTION.—Here $P = 1{,}600$, $W = 3{,}200$, and $Fc = 10$; hence,

$$Fb = \frac{P \times Fc}{W} = \frac{1{,}600 \times 10}{3{,}200} = 5 \text{ inches. Ans.}$$

58. Suppose that the weight arm Fb of the lever shown in Fig. 6 is twice as long as the power arm Fc; then, if the lever is turned about the fulcrum F until it occupies any other position, as $b' F c'$, it will be found by actual measurement that the point b of the lever travels just twice as far in moving to b' as c does in moving to c'. If the weight arm were four times as long as the power arm, it would be found that the point b would always travel four times as far as the point c when the lever was moved through any distance. In other words, the distances

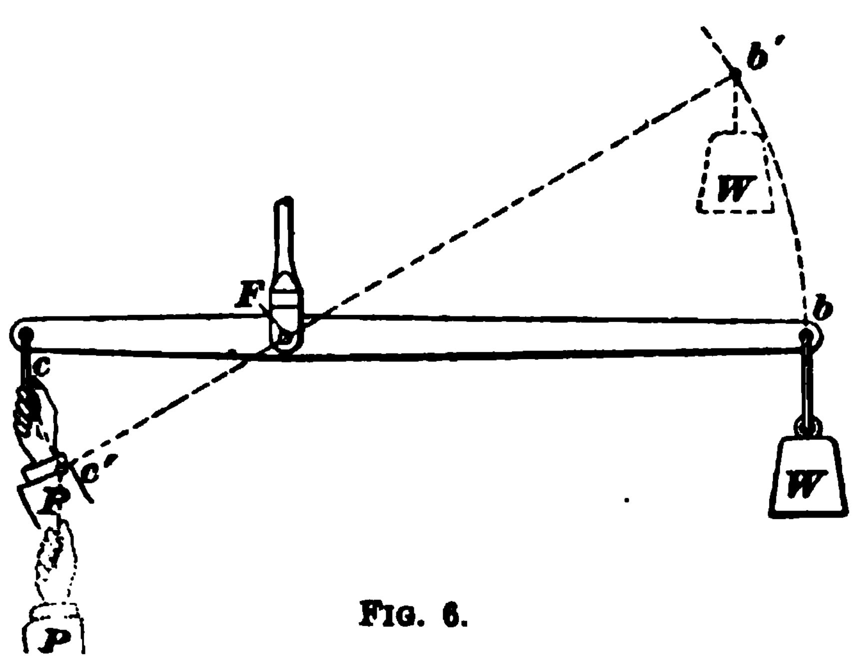


FIG. 6.

through which the power and the weight move are always in the same ratio as the lengths of their arms.

This being true, we may, in place of the statement that the power multiplied by the power arm is equal to the weight multiplied by the weight arm (rule I), write:

Rule II.—*The power multiplied by the distance through which the power moves is equal to the weight multiplied by the distance through which the weight moves.*

If the power moves through a distance $c\,c'$ while the weight moves through a distance $b\,b'$, then by substituting $c\,c'$ and $b\,b'$ for $F\,c$ and $F\,b$, respectively, in the equations (1) and (2) of Art. **57**, we have:

$$P = \frac{W \times b\,b'}{c\,c'}, \text{ and } W = \frac{P \times c\,c'}{b\,b'}.$$

EXAMPLE 1.—If the point of application b of the weight travels 2 inches while the point of application c of the power travels 8 inches, what force must be exerted on the lever to cause it to exert a force of 2,000 pounds?

SOLUTION.—In this case, $c\,c' = 8$, $b\,b' = 2$, and $W = 2{,}000$; hence,

$$P = \frac{W \times b\,b'}{c\,c'} = \frac{2{,}000 \times 2}{8} = 500 \text{ pounds. Ans.}$$

EXAMPLE 2.—In the above example, if a force of 1,000 pounds is applied at P, what force would the lever exert at W?

SOLUTION.—Here, again, the weight moves 2 inches while the power moves 8 inches; hence,

$$W = \frac{P \times c\,c'}{b\,b'} = \frac{1{,}000 \times 8}{2} = 4{,}000 \text{ pounds. Ans.}$$

The principle embodied in rule II was made use of by Mr. H. A. Wahlert in inventing a method for determining the braking power developed by a cam driver-brake.

59. Classes of Levers.—Levers are divided into three classes, depending on the relative positions of the fulcrum and the points of application of the power and the weight.

In levers of the *first class*, Fig. 3, the fulcrum F is between the points of application of the power P and weight W. Fig. 7 represents a car truck lever of this class applied to a car wheel.

In levers of the *second class*, Fig. 4, the weight W is between the fulcrum F and power P. This class is represented in Fig. 8, as applied to a car wheel.

In levers of the *third class*, Fig. 5, the power P is between the fulcrum F and the weight W. This class is represented in Fig. 9, as applied to a car wheel.

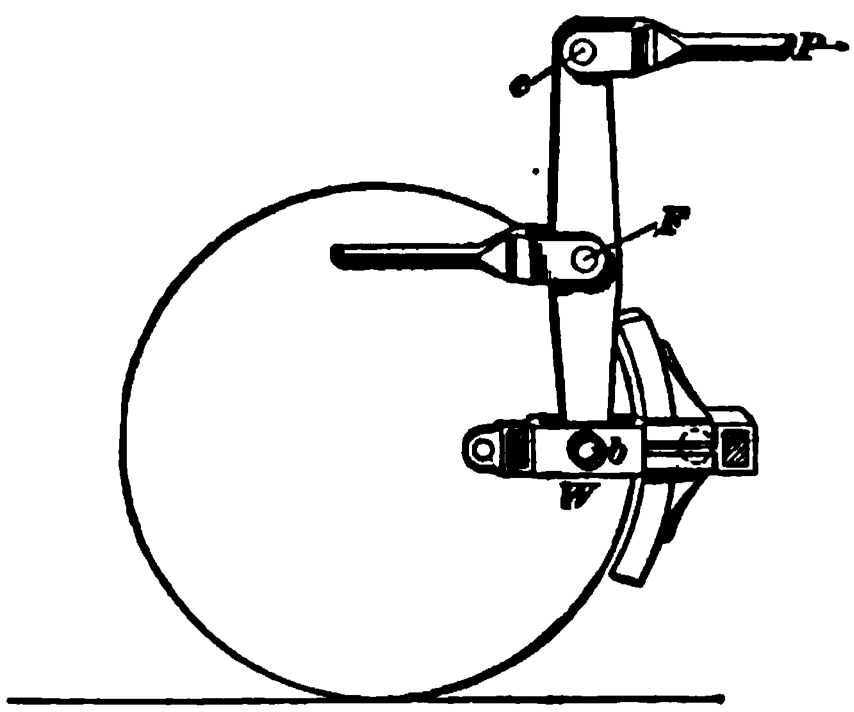


FIG. 7.

60. The Weight Sustained by the Fulcrum.—The force exerted on the fulcrum of a lever can be calculated by assuming that the fulcrum has changed places with either the power P or the weight W, and then using the proper equation. For instance, in example 1, Art. **57**, it was found that a force of 500 pounds at P would balance 1,000 pounds at W, the lever arms being 20 inches and 10 inches, respectively. Now, to find the force sustained at F, assume the fulcrum to have changed places with W. The power arm in that case would be $20 + 10 = 30$ inches long, while the weight arm would remain the same as before, or 10 inches, and we should have

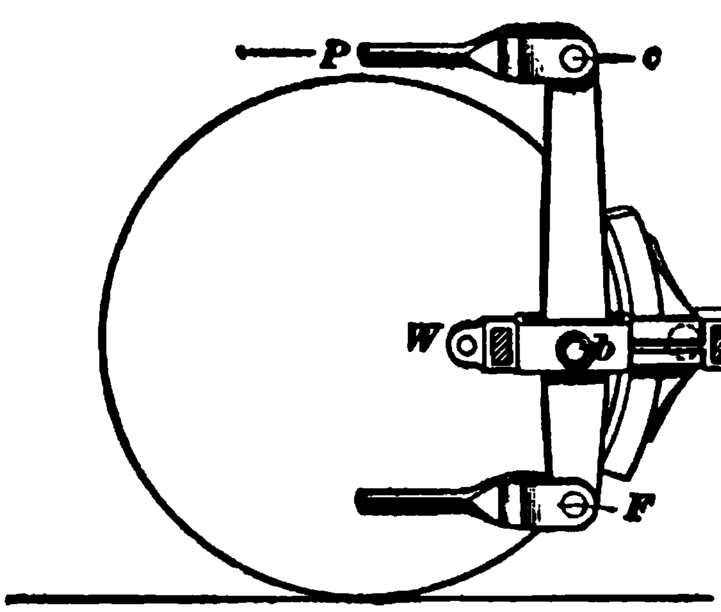


FIG. 8.

$$W = \frac{P \times Fc}{Fb} = \frac{500 \times 30}{10} = 1{,}500 \text{ pounds.}$$

This, it will be noticed, is equal to the sum of the power P and weight W.

If this method is applied to the three classes of levers, it will be found that: (1) the pressure on the fulcrum of a lever of the first class is equal to the sum of the power and weight;

(2) the pressure on the fulcrum of a lever of the second class is equal to the difference between the weight and the power; while (3) the pressure on the fulcrum of a lever of the third class is equal to the difference between the power and the weight.

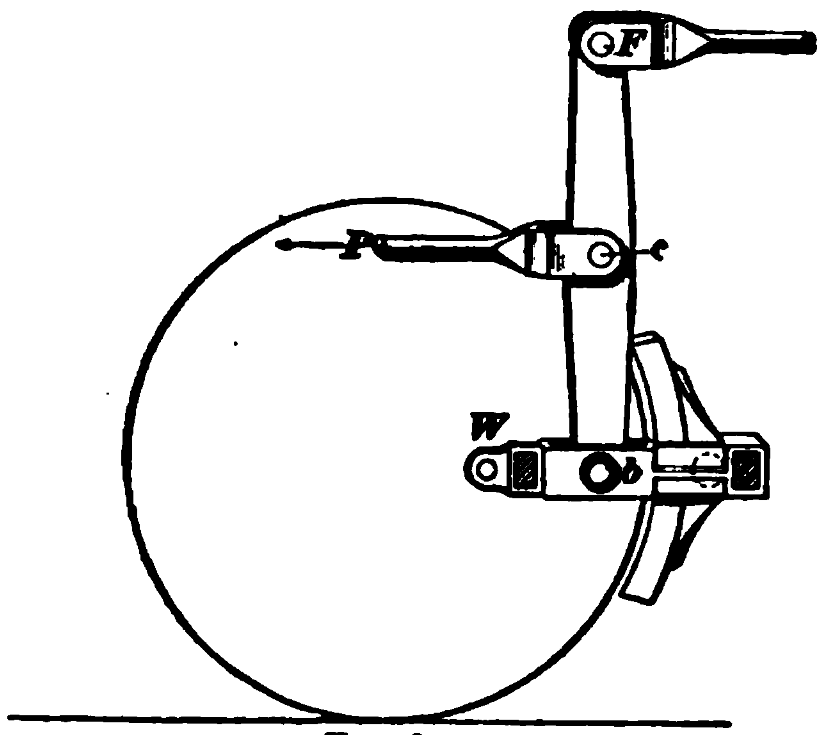


FIG. 9.

61. Bent Levers. All rules and equations that apply to the straight lever apply equally well to the **bent lever,** if care is taken to determine the *true* or *virtual* lengths of the lever arms. In the case of a straight lever with the forces acting at right angles to it, the arms may be measured along the lever itself; in all other cases (such as when: 1, the forces are parallel, but act at an angle to the lever; 2, the forces do not act parallel to each other; or 3, if the lever is bent), the weight arm or power arm must be taken as *the perpendicular distance from the fulcrum F to the line of direction in which the weight or power acts.*

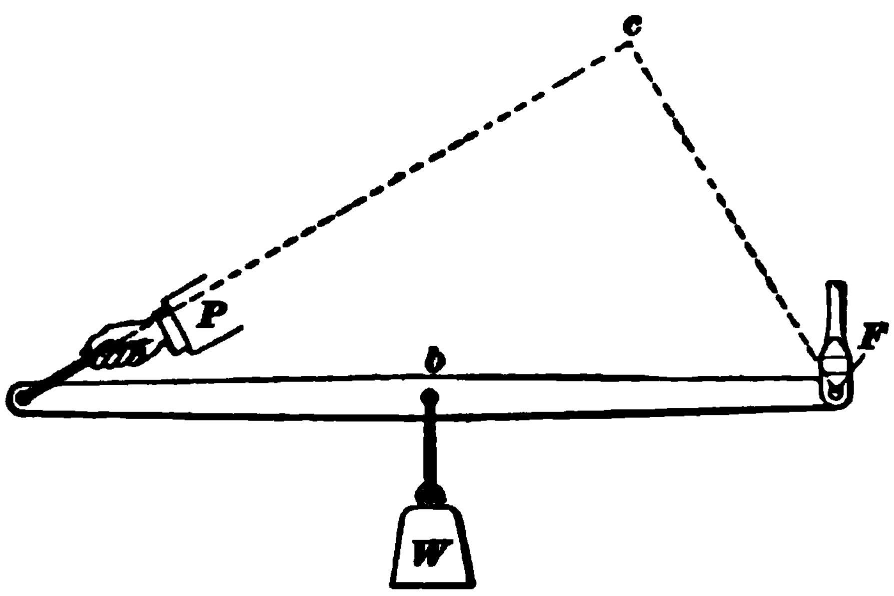


FIG. 10.

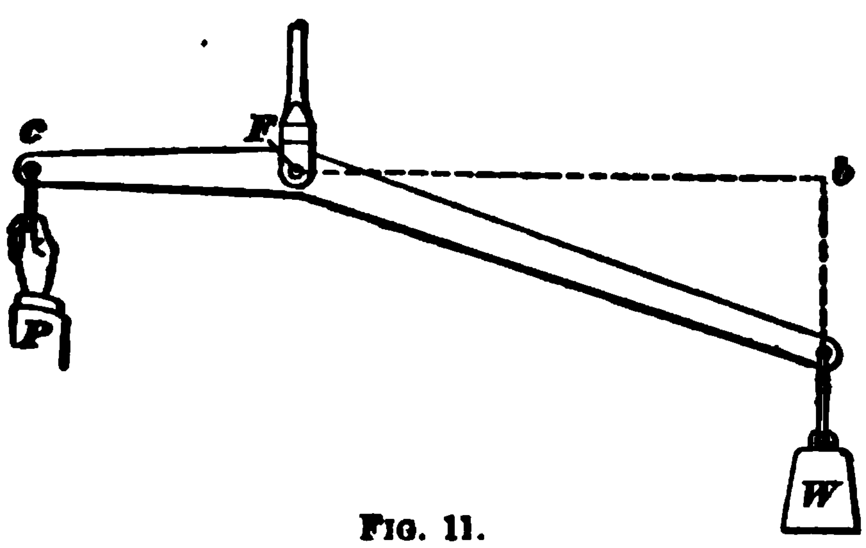


FIG. 11.

Figs. 11, 12, and 13 represent different styles of bent levers. In each case the power arm is represented by the line Fc, the weight arm being represented by the line Fb. Fig. 10 is dealt with in the same way.

COMPOUND LEVERS.

62. Description.—A **compound lever** is a combination of simple levers so arranged that when a power is applied to the first lever it actuates all of the others and causes a force to be exerted by the last lever of the combination. When a force

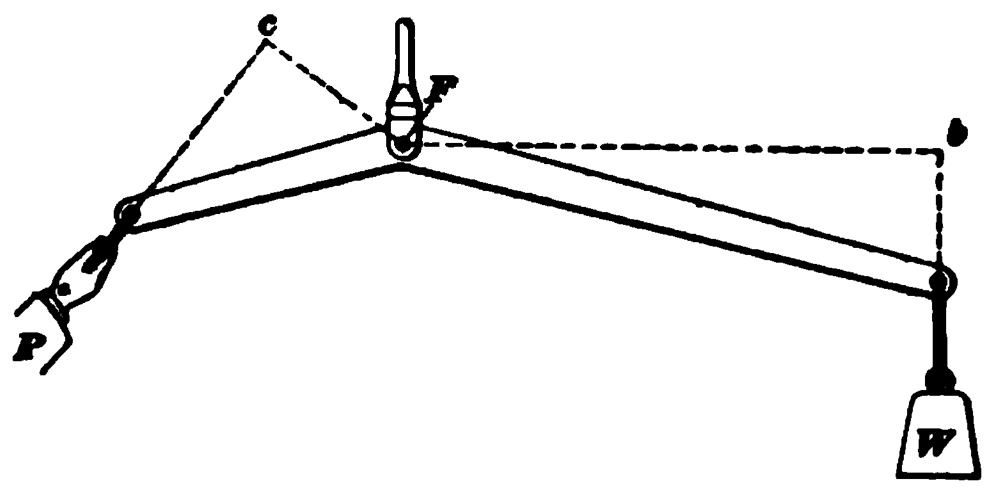


FIG. 12.

is applied to the first lever, it exerts a force that is applied to the second lever; the force exerted by the second lever is applied to the third; and so on.

Such a lever is shown in Fig. 14, in which there are three simple levers; the weight arm of the first is connected to the power arm of the second, and the weight arm of the second to the power arm of the third. It will be seen that by applying sufficient power at P to operate the first lever, the others will

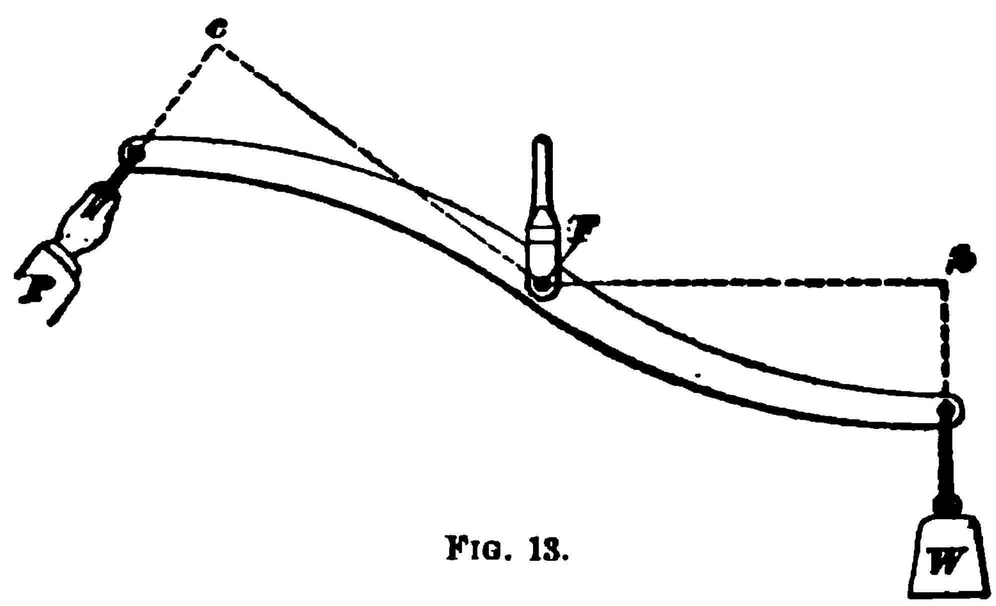


FIG. 13.

also be operated, and the weight W of the third lever will be raised.

It will be noticed, also, that the force exerted by the end of the weight arm of the first lever is the power applied to the second; and the force exerted by the second is the power applied to the third; and so on for any number of levers.

63. Law of the Compound Lever.—The law that governs the compound lever may be stated as follows: *The power P multiplied by the product of the power arms of all the component simple levers, is equal to the weight W multiplied by the product of the weight arms of all these levers.*

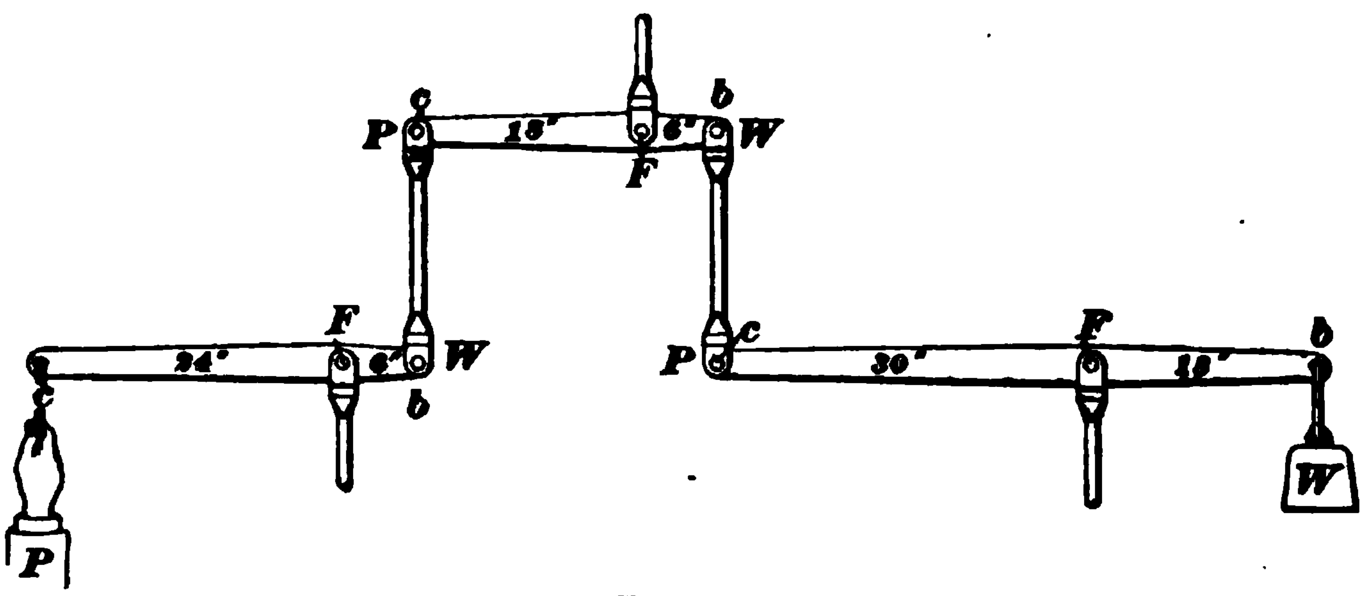


FIG. 14.

From this law the following rules may be deduced:

Rule III.—*The power P that must be applied to a compound lever to balance a given weight or produce a given pressure W, may be found by multiplying the product of the weight arms of all the simple levers by the weight, and dividing this by the product of the power arms of all these levers.*

EXAMPLE.—How much power must be applied at *P*, Fig. 14, to balance 1,000 pounds at *W*?

SOLUTION.—The weight arms of the levers are 6, 6, and 18 inches, and the power arms 24, 18, and 30 inches, respectively. Hence, from rule III, the power

$$P = \frac{6 \times 6 \times 18 \times 1{,}000}{24 \times 18 \times 30} = 50 \text{ pounds. Ans.}$$

Rule IV.—*The weight that a given power will balance, when applied to a compound lever, may be found by multiplying the product of the power arms of all the simple levers by the power, and dividing this by the product of the weight arms of all the levers.*

EXAMPLE.—If a force of 50 pounds is applied at *P*, Fig. 14, how many pounds will it balance at *W*?

SOLUTION.—From rule IV it will be found that 50 pounds at *P* will balance a weight of

$$W = \frac{24 \times 18 \times 30 \times 50}{6 \times 6 \times 18} = 1{,}000 \text{ pounds. Ans.}$$

LAWS OF LEVERS APPLIED TO BRAKE GEARS.

64. In order to apply these laws to any particular system of levers, it is best to make a diagram showing the position of the fulcrums, the length of the lever arms, and the line of direction of the forces applied to, or exerted by, the levers. Then, since the force developed by the brake cylinder is generally known, the power exerted by the lever can be readily found by applying the proper rules or formulas.

To illustrate the application of the laws of levers to actual brake gears, the braking power of the Hodge and the Stevens systems of car-brake levers, and of the cam and the American equalized types of driver brakes will be determined.

65. The Hodge System.—A diagram of the **Hodge** system is shown in Fig. 15. It will be seen to consist of two compound levers operated by the same brake cylinder, each compound lever consisting of four simple levers. The first of these is called the *cylinder lever;* the second, the *floating lever;* the third, the *truck live lever;* while the fourth is called the *truck dead lever*. The fulcrum of each lever is marked F, and the points at which the power and weight are applied are marked P and W, respectively. The right and left cylinder levers are of the first and third classes, respectively; the floating levers are of the third class; while the truck live levers and truck dead levers are of the first and the second class, respectively. The brake cylinder is assumed to exert 4,700 pounds pressure in an emergency application.

Calculating the Power of the Hodge System.—To calculate the power applied to the brake shoes, it is now simply a question of using the proper rules for the separate levers. For the first, or cylinder lever, $P = 4{,}700$; therefore,

$$W = \frac{4{,}700 \times 15}{15} = 4{,}700 \text{ pounds},$$

and this is the force applied to P of the floating lever.

The pressure on the fulcrum F of the cylinder lever is equal to the sum of P and W, or 9,400 pounds (see Art. **60**). P of

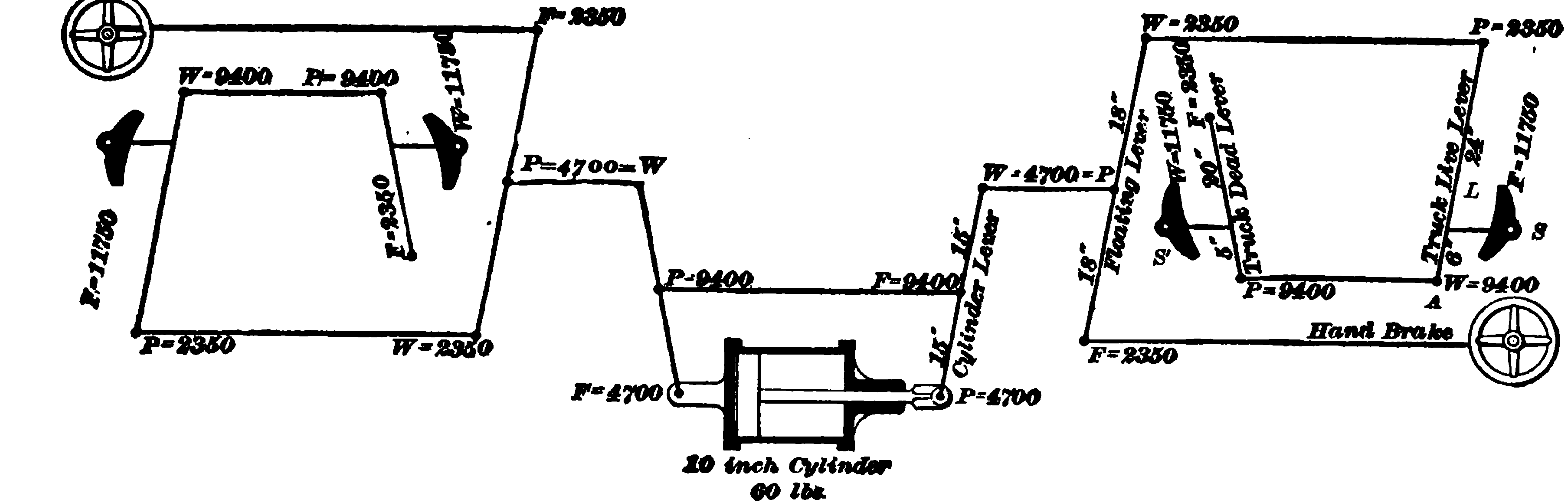

P=2350
W=9400
P=9400
W=11750
F=2350
F=11750
P=2350
W=2350
P=4700=W
P=9400
F=9400
F=4700
P=4700
15"
15"
Cylinder Lever
10 inch Cylinder
60 lbs.
W=4700=P
18"
18"
Floating Lever
W=2350
W=11750
F=2350
20"
5"
Truck Dead Lever
S
P=9400
P=2350
Truck Live Lever
24
L
6"
F=11750
S
W=9400
A
Hand Brake
F=2350

FIG. 15.

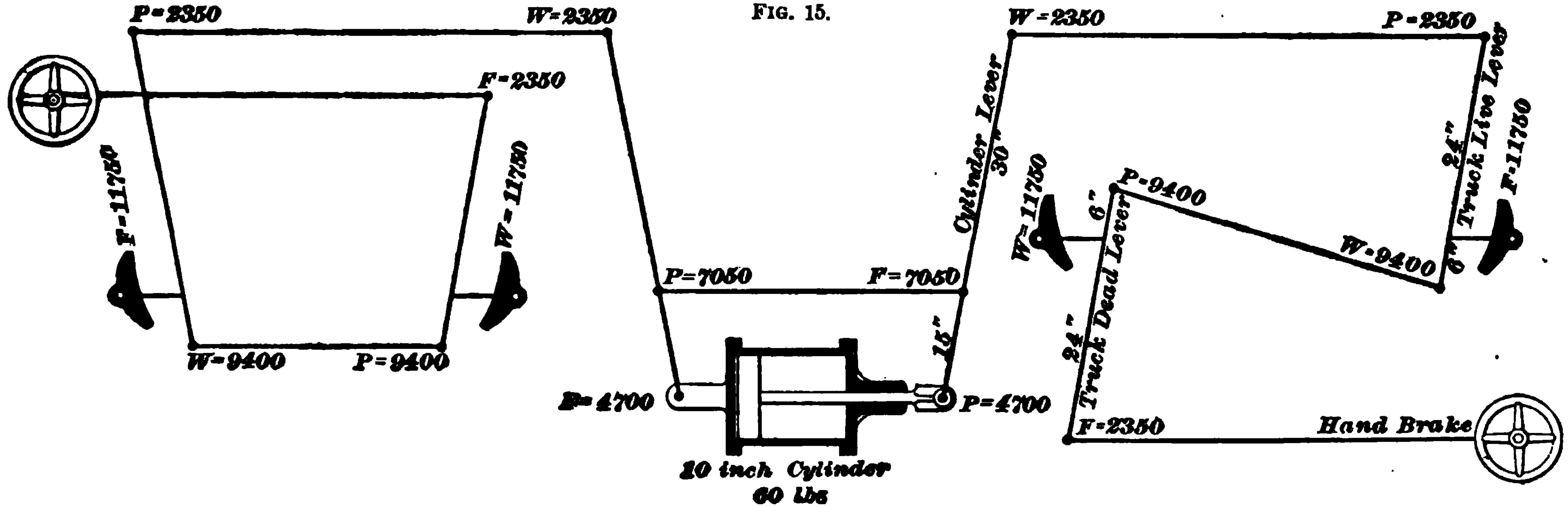

P=2350
W=2350
F=2350
F=11750
W=11750
W=9400
P=9400
P=7050
F=7050
F=4700
P=4700
15"
Cylinder Lever
30"
10 inch Cylinder
60 lbs
W=2350
P=2350
Truck Live Lever
24"
6"
F=11750
W=11750
6"
P=9400
W=9400
24"
Truck Dead Lever
F=2350
Hand Brake

FIG. 16.

the floating lever is 4,700, as already remarked; therefore,

$$W = \frac{4,700 \times 18}{36} = 2,350 \text{ pounds},$$

and the pressure on F of this lever is $4,700 - 2,350 = 2,350$ pounds. P of the truck live lever is 2,350 pounds; therefore,

$$W = \frac{2,350 \times 24}{6} = 9,400 \text{ pounds},$$

and the force applied to the wheels at F is $9,400 + 2,350 = 11,750$ pounds. P of the truck dead lever is 9,400; hence,

$$W = \frac{9,400 \times 25}{20} = 11,750 \text{ pounds},$$

the force applied to the wheels, while the force exerted at the fulcrum F is $11,750 - 9,400 = 2,350$ pounds.

The calculations for the left-hand compound lever are made in the same way, beginning with 9,400 pounds applied to P of the cylinder lever.

We may remark here that the truck live lever L may also be regarded as a lever of the second class, the relative positions of power, weight, and fulcrum then being as noted in Fig. 8. If we have in mind the exerting of a force on shoes S, then the end A of lever L must be regarded as the fulcrum. If, on the other hand, we are considering the exerting of a force on the shoes S', then the point of contact of S on its wheel becomes the fulcrum. Thus, the lever L is, at one and the same time, a lever of the first or the second class, according to the point of view we take, that is, whether we are considering the question of exerting a pressure on S or on S'. In either case, of course, the numerical results are the same.

66. The Stevens System.—The Stevens system of car-brake levers is shown in diagram in Fig. 16. It will be noticed that in this system there are no floating levers, the cylinder levers being lengthened sufficiently to allow the weight arm to be coupled directly to the truck live lever. It will be noticed, also, that all of the simple levers are of the first class, except the left-hand cylinder lever, which is of the third class, and the two truck dead levers, which are of the second class.

Calculating the Power of the Stevens System.—To calculate the power applied to the brake shoes in this system of levers, proceed as with the Hodge system, bearing in mind what was said in Arts. **59** and **60**. For example, if the brake cylinder exerts a force of 4,700 pounds, a force of

$$\frac{4,700 \times 15}{30} = 2,350 \text{ pounds}$$

will be exerted at W of the cylinder lever, while the force F on the fulcrum will equal $4,700 + 2,350 = 7,050$ pounds. 2,350 pounds applied to P of the truck live lever will cause a force of

$$\frac{2,350 \times 24}{6} = 9,400 \text{ pounds}$$

to be exerted at W, while the force on the fulcrum F (the brake shoes) will be $9,400 + 2,350 = 11,750$ pounds. With a force of 9,400 pounds exerted at P of the truck dead lever, a force of

$$W = \frac{9,400 \times 30}{24} = 11,750 \text{ pounds}$$

will be applied to the brake shoes, while the fulcrum F will be subjected to a force of $11,750 - 9,400 = 2,350$ pounds. The force applied to the other brake shoes can be found in a similar manner.

As regards the leverage of the truck live lever, the last paragraph of Art. **65** applies here also.

67. Cam Driver-Brake.—The following very simple method for determining the braking power developed by a cam driver-brake was invented by Mr. H. A. Wahlert, of the American Brake Company:

Take two pieces of wire of the same diameter and place them between the top and bottom toes of one of the brake shoes and the wheel; then apply the brakes fully and measure the piston travel. Next, release the brakes, recharge fully, and again apply the brakes in full with the wires removed. Measure the piston travel and find how much it increases when the wires are removed. The wires are used to find the relative amount

of travel of the weight arm (the brake shoe) and power arm (the piston); by subtracting the amount of piston travel when the wires are in place from the amount when they are removed, the distance the piston travels while the brake shoe travels the thickness of the wire can be determined. Knowing the relative travel of the brake shoe and piston, and the force developed by the cylinder, the force exerted on one brake shoe can be determined by rule II, Art. **58**. The rule, as applied to this case, may be stated as follows: *The force exerted on one brake shoe of a cam driver-brake is found by multiplying the increase of piston travel* (determined as above) *by the force developed in the brake cylinder* (in pounds), *and dividing the result by the*

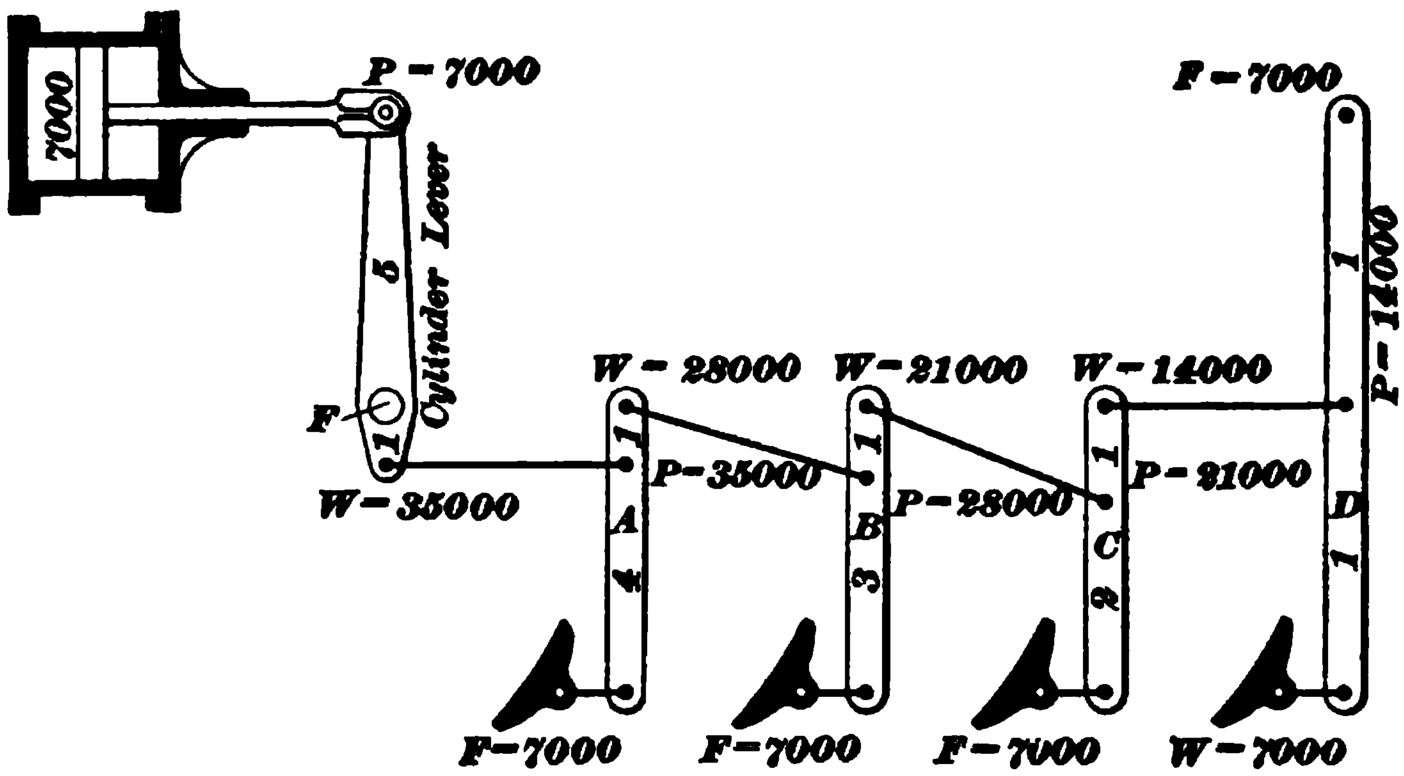


Fig. 17.

diameter (in inches) *of the wire used.* To find the total force exerted on the four shoes, multiply this amount by 4.

As an example of the use of this rule, suppose the diameter of the wires used to be $\frac{1}{8}$ inch, the piston travel with the wires inserted to be 4 inches, and when removed, $4\frac{1}{2}$ inches. In this case the increase in piston travel would be $4\frac{1}{2} - 4 = \frac{1}{2}$ inch. Then, if a total force of 2,500 pounds were developed by the brake cylinder, the force exerted on each brake shoe would be

$$W = \frac{2{,}500 \times \frac{1}{2}}{\frac{1}{8}} = 10{,}000 \text{ pounds.}$$

This would give a total force on the four shoes of $4 \times 10{,}000 = 40{,}000$ pounds.

68. American Outside Equalized Brake.—This type of brake was illustrated in Fig. 2, Art. **55**, and a diagram of it, as applied to an engine having four pairs of drivers, is given in Fig. 17. In a brake of this kind, the levers are so proportioned that the braking power developed at the brake cylinder is distributed equally among the drivers, the force applied to the different brake shoes being maintained equal; hence, the brake is said to be an equalized brake.

In the figure, the cylinder lever is of the first class, while the others are of the third class, the relative lengths of the lever arms being given in each case. The total force developed in the brake cylinder is, say, 7,000 pounds. This will cause a force of

$$\frac{7{,}000 \times 5}{1} = 35{,}000 \text{ pounds}$$

to be exerted at P of lever A, which in turn will cause a force of

$$W = \frac{35{,}000 \times 4}{5} = 28{,}000 \text{ pounds}$$

to be exerted at P of lever B. The force applied at the fulcrum (the brake shoes) of lever A is $35{,}000 - 28{,}000 = 7{,}000$ (see Art. **60**). 28,000 pounds at P of lever B will exert at P of lever C a force of

$$W = \frac{28{,}000 \times 3}{4} = 21{,}000 \text{ pounds,}$$

and a force of $28{,}000 - 21{,}000 = 7{,}000$ pounds will be exerted at the fulcrum (brake shoes) of lever B. A force of

$$W = \frac{21{,}000 \times 2}{3} = 14{,}000 \text{ pounds}$$

will be exerted at P of lever D, while $21{,}000 - 14{,}000 = 7{,}000$ pounds will be exerted on the shoes of lever C. 14,000 pounds at P of lever D will exert a force of

$$W = \frac{14{,}000 \times 1}{2} = 7{,}000 \text{ pounds}$$

at the shoes, and $14{,}000 - 7{,}000 = 7{,}000$ pounds at the fulcrum F.

For an engine having two pairs of drivers, the end *W* of the cylinder lever would be connected at *P* of lever *C*, and levers *A* and *B* would not be used. A force of 21,000 pounds would have to be exerted by the cylinder lever to give 7,000 pounds at each brake shoe, so that if the same size cylinder were used, the power arm of the cylinder lever would have to be three times as long as the weight arm.

On an engine having three pairs of drivers, the cylinder lever would be connected to the lever *B*, and would have to exert 28,000 pounds to give 7,000 pounds at each brake shoe; hence, if the brake cylinder were of the same size as that just considered, the power arm of the cylinder lever would have to be four times as long as the weight arm.

BRAKE POWER.

PRESSURES APPLIED TO BRAKE SHOES.

69. In Art. **45** the statement was made that if the frictional resistance exerted between the wheel and the shoe were greater than that exerted between the wheel and the rail, the wheel would slide. With a good rail, these frictional resistances will be practically equal when the force applied at the brake shoe is equal to the pressure of the wheel on the rail, so that the force applied to the brake shoe must be less than the pressure of the wheel on the rail, to insure the wheel against slipping when used under the varying conditions of service. Practical experience has demonstrated that the best results will be obtained by the use of the following as *the maximum safe pressures* on the brake shoes in the different classes of service: For passenger cars, $\frac{9}{10}$, or 90 per cent., of the weight on the rail under the wheel when the car is empty; for freight cars, $\frac{7}{10}$, or 70 per cent., of the weight on the rail when the car is empty; for tenders, 100 per cent., or the entire weight on the rail when the tender is light; for driving wheels, $\frac{75}{100}$, or 75 per cent., of the weight under the drivers when the engine is ready for the road.

CALCULATION OF BRAKING POWER.

70. The method of calculating *the proper braking power* to use in any case is as follows: First find the weight on the rail under each wheel, by dividing the entire weight of the empty car by the number of wheels. Then, if the car is a passenger car, take $\frac{9}{10}$ of this, or, if a freight car, take $\frac{7}{10}$, as the maximum force to be used on each brake shoe. In other words, this is the allowable force per shoe; therefore, the total braking force can be found by multiplying this amount by the number of wheels that are fitted with brakes, and from this the proper proportion of brake levers can be determined.

The sizes of brake cylinders that are used on cars and tenders of different weights are as follows: 6-inch brake cylinders are used on freight cars having a light weight of 15,000 pounds or less; 8-inch cylinders on tenders of 35,000 pounds light weight or less, and also on freight cars whose light weight is between 15,000 and 42,000 pounds; 10-inch cylinders on tenders of over 35,000 pounds light weight, and also on passenger cars of 50,000 pounds or less; 12-inch cylinders on passenger cars whose light weight is between 50,000 and 70,000 pounds; and 14-inch cylinders on passenger cars of over 70,000 pounds.

EXAMPLE.—What is the maximum braking power that should be allowed at each brake shoe of a 72,000-pound passenger car having 6-wheeled trucks, 4 wheels only of each truck being supplied with brakes? Also, what will be the total braking force?

SOLUTION.—If this car weighs 72,000 pounds and has 12 wheels, there will be a pressure of $\frac{72,000}{12} = 6,000$ pounds on the rail under each wheel; hence, the highest allowable braking force per wheel should be $.9 \times 6,000 = 5,400$ pounds. The total allowable braking force of the car, therefore, will be $8 \times 5,400 = 43,200$ pounds, since only 8 wheels are braked.

71. The Force Exerted in the Brake Cylinder.—The total allowable braking force should not be exceeded when an emergency application of the brakes is made, since at such times it is especially important that no wheels slide, as a sliding wheel exerts but little retarding force. For this reason, the

braking power is calculated on the assumption that, in an emergency application, 60 pounds pressure is obtained in the brake cylinder with a quick-action brake, and 50 pounds with a plain triple.

The total force in pounds that a brake cylinder will develop when subjected to 50 and 60 pounds pressure per square inch, has been calculated for several sizes of cylinders, and the results tabulated as follows:

FORCE EXERTED IN BRAKE CYLINDER.

Size of Cylinder. Inches.	With 50 Lb. Pressure.	With 60 Lb. Pressure.
6	1,400	1,700
8	2,500	3,000
10	3,900	4,700
12	5,600	6,800
14	7,700	9,200

The force exerted in a brake cylinder is found by multiplying the area of the piston in square inches by the pressure per square inch in the cylinder. Thus, if the piston has an area of 154 square inches, it will develop a force of $154 \times 50 = 7,700$ pounds under a 50-pound pressure.

The area of the piston may be found by multiplying the diameter of the piston (in inches) by itself, and by 11, and dividing the product by 14. Thus, the area of a 10-inch piston is $\frac{10 \times 10 \times 11}{14} = 78\frac{1}{2}$ square inches, about. The areas of various sizes of pistons used in the brake system are as follows: $28\frac{1}{4}$ square inches area in a 6-inch piston, $50\frac{1}{4}$ in an 8-inch, $78\frac{1}{2}$ in a 10-inch, 113 in a 12-inch, and 154 in a 14-inch, piston.

Another, and slightly more accurate, method of calculating the area of a piston is to multiply the diameter (in inches) by itself, and by .7854.

THE AIR BRAKE.

(PART 4.)

TRAIN AIR-SIGNALING SYSTEM.

GENERAL ARRANGEMENT OF APPARATUS.

1. The general arrangement of the train **air-signaling apparatus** on an engine, tender, and passenger car is shown in Figs. 1 and 2. This system has gradually taken the place of the old bell-cord-and-gong method of signaling on passenger trains, on account of the ease and certainty with which signals can be transmitted to the engineer from any part of the train.

The engine, tender, and each of the cars are piped with a $\frac{3}{4}$-inch pipe, which is connected between cars by means of hose, so that when all the hose is coupled, the signal-pipe line extends throughout the entire train.

A *car discharge valve*, Fig. 1, is provided on each car. This is usually located outside the car above the door, as shown in the figure, and is piped to the train signal pipe. Sometimes, however, it is placed inside the car above the door, to guard against the valve being clogged in winter. The former position is preferable, however, as the chances of clogging are small, and the annoyance caused by the sharp sound of discharging air every time the valve is opened to make signals is avoided.

A signal cord is attached to the lever of the discharge valve, and one end extends across the platform and is fastened in a suitable manner to the hood, while the other end extends through the car and is fastened to the hood on the other end of the car. This cord enables the discharge valve to be operated from any part of the car.

The air-signal apparatus on the engine, Fig. 2, consists of the *signal valve*, *signal whistle* and *pressure-reducing valve*. A $\frac{3}{8}$-inch pipe leads from the main reservoir to the reducing valve, and thence leads to, and connects with, the T-fitting *s* in the

signal pipe. Air from the main reservoir can thus pass through the pressure-reducing valve and thence into the signal pipe and signal valve, but at a reduced pressure. A pressure of 40 pounds with the improved valve, and 25 with the old valve, is

usually maintained in the signal system, and the duty of the reducing valve is to diminish the pressure from 90 pounds

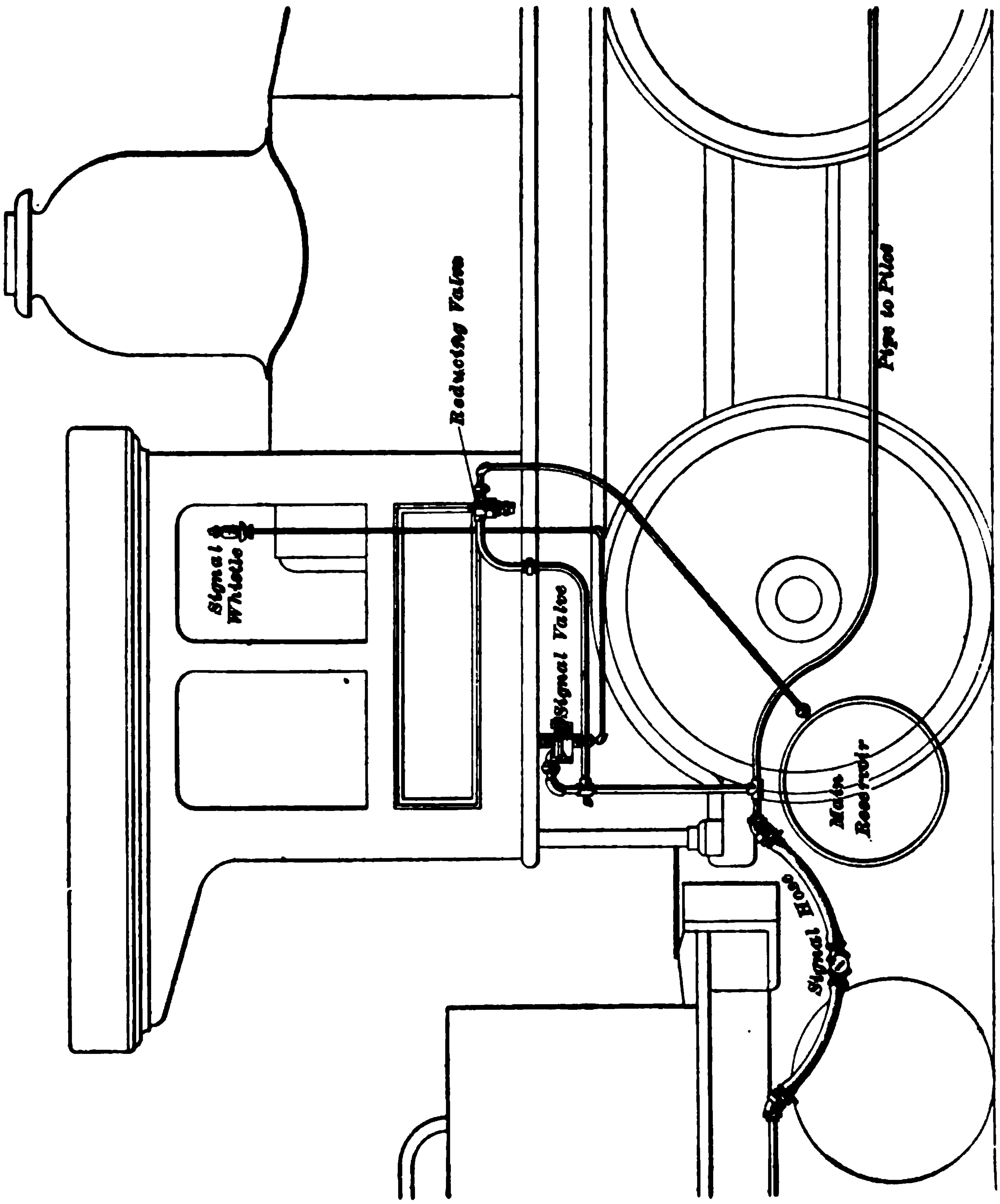


FIG. 2

(main-reservoir pressure) down to the required pressure for use in the signal system.

The **signal whistle,** Fig. 3 (a small whistle located in the cab, as close to the engineer as practicable), is piped to the signal valve, and it is the operation of the latter that causes the whistle to blow.

When the conductor wishes to transmit a signal to the engineer, he gives the signal cord in one of the cars a pull. This opens the car discharge valve on that car and allows some of the air in the main signal line to escape to the atmosphere, thus reducing the signal-pipe pressure. The reduction in pressure operates the signal valve on the engine, which, consequently, discharges a small quantity of air through the signal whistle in the cab, thus causing it to sound a short blast. Each time the cord is pulled, the signal whistle gives a blast.

Fig. 3.

DESCRIPTION OF APPARATUS.

REDUCING VALVE (OLD STYLE).

2. Although this style of **reducing valve,** Fig. 4, has been superseded to a great extent by the improved valve, there are still a sufficient number in use to warrant a description of them being given here.

The main-reservoir connection is made at *X*, while a pipe leads from *Y* to the signal pipe. *4* is the supply valve that regulates the admission of air to the signal system; it is operated by the stem of the reducing-valve piston *8* and by the supply-valve spring *10*. *7* is the rubber diaphragm; *6*, the diaphragm ring; and *9*, the regulating spring. In this style of valve, the spring *9* was made strong enough to just resist a pressure of 25 pounds per square inch in chamber *B*. In some instances, however, it has been replaced by a spring that requires 40 pounds pressure per square inch to compress it. The outlets *e*, *e*, in the cap *3* prevent air (due to leakage)

from accumulating back of the piston and piston stem and rendering the valve inoperative.

FIG. 4.

8. Operation of Valve.—The operation of this valve is as follows: The spring *9*, acting on the piston *8*, causes the stem of the piston to hold supply valve *4* from its seat, so that

main-reservoir air entering at *X* is free to pass through the passages *2*, *2*, past valve *4* and into chamber *B*, and thence through the outlet *Y* to the signal line. This increases the pressure in the signal pipe and chamber *B* until it reaches 25 pounds per square inch, when the diaphragm *7* and piston *8* are forced upwards against the action of the spring *9*. The supply-valve spring *10* then forces the supply valve to its seat, and prevents the further passage of air from the main reservoir to the train pipe. As long as the pressure in chamber *B* remains at 25 pounds, spring *9* will be compressed and the supply valve will remain closed. Any reduction of pressure in chamber *B*, however, will cause the regulating spring to force the diaphragm *7* and piston *8* downwards, thus forcing the supply valve from its seat and allowing sufficient air to pass to the signal pipe to again raise its pressure to 25 pounds, when the supply valve will close. The old-style valve has no regulating nut by means of which the tension of the regulating spring can be adjusted to alter signal-pipe pressure. If it is necessary to increase the signal-pipe pressure, the regulating spring *9* will have to be replaced by one that is stiffer; or a couple of washers may be placed in the cap nut, the effect of which will be to compress the spring more, and thus make it offer a greater resistance to the upward motion of piston *8*.

REDUCING VALVE (IMPROVED).

4. The **improved reducing valve** is shown in Fig. 5; *2* is a plug cock which, in the position here shown, is allowing air to enter the reducing valve, but, when turned at right angles to its present position, cuts the valve out of service; *3* is the lower cap; *4*, the supply valve; *5*, the supply-valve cap nut; *6*, the supply-valve spring; *7*, the reducing-valve piston; *8*, a rubber diaphragm consisting of two pieces of rubber; *9*, the regulating spring; *10*, the diaphragm ring; *11*, the piston packing-ring (which, together with the diaphragm, serves to prevent leakage of air past piston *7*); *14*, the regulating nut by means of which the tension of the spring *9* is adjusted; and *15*, the

check-nut. The passage *e* is to allow any air leaking past the piston *7* to escape to the atmosphere.

5. Operation of Valve.—The tension of the regulating spring *9* is adjusted to just withstand a pressure of 40 pounds

FIG. 5.

per square inch in chamber *B*. When the pressure is less than this amount, the spring *9* forces piston *7* upwards and the piston stem unseats the supply valve *4*. Main-reservoir air (entering at *X*) is then free to pass through the plug cock *2*,

supply valve *4*, and thence out through *Y* to the signal pipe. As soon as the pressure in the signal pipe and chamber *B* reaches 40 pounds, piston *7* is forced downwards and the spring *6* then forces the supply valve to its seat, closing communication between the main reservoir and the signal pipe. Any reduction in signal-pipe pressure will allow the spring *9* to force piston *7* upwards, thus opening the supply valve again. The valve then remains open until the signal-pipe pressure is again raised to 40 pounds, when it closes. The reducing valve should be placed in the cab, in some moderately warm place, if possible, so as to prevent its freezing in cold weather.

With the improved valve, the signal-pipe pressure may be increased by screwing up the regulating nut *14*, or decreased by unscrewing this nut.

CAR DISCHARGE VALVE.

6. A sectional view of the **car discharge valve** is shown in Fig. 6, in which *3* is the discharge valve, and *4* the discharge-valve spring that holds this valve up against its seat. *5* is the lever or handle to which the signal cord is attached, while *6*, *6* are stop-pins. There is a union connection at *a* to which the branch pipe from the signal pipe is connected, while the exhaust port *b* leads to the atmosphere.

Fig. 6.

7. Operation of Valve.—When the signal cord on either side of the discharge valve is pulled, the lever *5* is caused to strike the stem of the discharge valve *3* and force the valve

from its seat. Air from the signal pipe then passes up through the branch pipes and out to the atmosphere through the union connection *a* and the port *b*, causing a reduction in signal-pipe pressure. As soon as the signal cord is released, the spring *4* forces the discharge valve to its seat again and stops the discharge of air from the signal pipe.

Referring to Fig. 1, it will be seen that the branch pipe to the discharge valve is supplied with a strainer (where it connects with the main signal pipe) and a cut-out cock, the former to prevent dirt from reaching the discharge valve, and the latter to enable the discharge valve to be cut out in case it is disabled. The handle of the cut-out cock stands parallel with the pipe when the discharge valve is cut out, and at right angles to it when cut in. Also, the cut-out cocks in the signal pipe on either side of the signal hose are closed when the handles stand parallel with the pipe, and open when at right angles to it.

THE SIGNAL VALVE.

8. The signal valve, Fig. 7, is located under the footboard of the cab, and may be placed either on the engineer's or the fireman's side. The signal pipe is connected to it at *X*, while a pipe leads from *Y* to the signal whistle. The valve body is divided into two chambers *A* and *B* by the rubber diaphragm *12*, which also is attached to and operates the diaphragm stem *10*. This stem extends through the bushing *9*, and its end forms a valve (with seat in bushing *7*) that controls the passage *e* leading to the whistle. A small portion of the stem *10* fits the bushing *9* rather snugly, while below this a groove *f* is cut around the stem. Below this groove the stem is milled out so as to have a cross-section like that shown at *x*.

9. Operation of Valve.—When the signal pipe is being charged, air enters the signal valve at *X*, and, passing through the small port *d*, charges chamber *A*. It also passes through the passage *c c*, and feeds up slowly past the stem *10* into chamber *B*, charging this to the same pressure as chamber *A*. The pressures in chambers *A* and *B* and the signal pipe are equal when the pipe is fully charged.

When the signal cord is pulled and a reduction is made in the signal pipe, it causes a reduction of pressure in the signal valve also; but, since the stem *10* makes a rather snug fit, the pressure in chamber *A* above the diaphragm reduces faster than the pressure in chamber *B*; consequently, the diaphragm is forced upwards, and raises the stem *10*, thus opening the

Fig. 7.

exhaust valve in *7*. The stem *10* is lifted until the groove *f* is above the bushing *9*, when the air in chamber *B* escapes quickly through the groove *f*, the milled spaces in the stem *10*, and the passage *e*, out to *Y* and the whistle, causing the latter to give a blast. Air also escapes from chamber *A* to the whistle, through the passages *c c* and *e*.

The same reduction of pressure that operates the signal valve also opens the reducing valve, allowing air from main reservoir to flow into, and raise the pressure in, the signal line. This increase of pressure, following the closing of car discharge valve,

and immediately after the reduction in signal valve, increases the pressure in chamber *A* faster than in chamber *B*, thus forcing the diaphragm downwards, closing the valve leading to passage *e*, and stopping the blast of the whistle.

SIGNALING.

10. In **transmitting signals** by means of the air-signaling system, certain precautions must be observed in order to obtain good results. For each blast of the whistle, the car discharge valve should be held open just long enough to reduce the pressure in the signal pipe clear up to the signal valve on the engine, when it should be closed. It should then be allowed to remain closed until the pressure has equalized throughout the system, before it is again opened to transmit another signal. If the discharge valve is opened a second and, possibly, a third time before the whistle has ceased to blow due to the first reduction, the whistle will give one long blast instead of two or three short ones, as intended. If it is opened a second time before the pressure has fully equalized in the signal pipe, the whistle will give a blast after each discharge, but the last blast will be weak on account of the pressure being less than 40 pounds.

In transmitting signals, the best results will be obtained if the car discharge valve is allowed to remain closed from 2 to 3 seconds between blasts, depending on the length of the train. In other words, for each blast, pull the signal cord straight downwards and hold the discharge valve open for 1 second; then allow from 2 to 3 seconds for the pressure to equalize throughout the signal pipe before it is again opened for another blast.

DEFECTS IN THE SIGNALING SYSTEM.

11. Although there are but comparatively few parts in the air-signaling system, it requires good judgment to locate defects that cause incorrect signals to be given. Also, it should be borne in mind that it is not so much the *amount* of the reduction as the *rapidity* with which it is made, that causes the whistle to blow.

SIGNAL PIPE FAILS TO CHARGE.

12. If it is found that no air passes into the signal pipe, first see whether the cocks on each side of the hose between the tender and train have been opened. If so, the opening in the plug *16* of the reducing valve, Fig. 5, may be stopped up with oil and dirt; or the lining in the hose may be loose and blocking the passage; or, if the weather is cold, the signal pipe on the engine or tender may be stopped up with ice, or the reducing valve may be frozen up.

NO EXHAUST FROM DISCHARGE VALVE.

13. If no exhaust occurs at the discharge valve when the signal cord is pulled, the signal pipe being properly charged, the trouble may be due to the cut-out cock, Fig. 1 (usually placed in the saloon), being turned so as to cut out the discharge valve.

WHISTLE FAILS TO BLOW.

14. If an exhaust occurs at the discharge valve when the signal cord is pulled, but the signal whistle fails to give a blast, the trouble may be due to the strainer in the **T**, where the branch pipe connects with the signal pipe, being stopped up (see Fig. 1). In this case, the exhaust may sound all right, since there is considerable air in the branch pipe between the strainer and the discharge valve, but the air in the main pipe cannot get past the strainer fast enough to make a sufficiently quick reduction to operate the signal valve. If the trouble is not in the strainer, it may be that (1) port *d* of the signal valve is stopped up, in which case no air can enter the valve to charge it; (2) stem *10* of signal valve has worn sufficiently loose in bushing *9* to allow pressure in chamber *B* to reduce about as fast as that in chamber *A*; (3) the signal-valve diaphragm is bagged or, possibly, cracked; (4) the bell of the signal whistle is imperfectly adjusted or its bowl is full of dirt; (5) whistle is so situated that wind blowing across the bowl prevents it from sounding; or (6) dirt in port of bushing *7*.

If poor rubber is used in the diaphragm, or if oil gets on it, the rubber will, in time, stretch and bag. In that event, when a signal-pipe reduction is made, the diaphragm will respond to it without raising the stem *10* from its seat in *7*, and no blast will result. An overheated air pump also tends greatly to heat the rubber and buckle or distort the diaphragm. In some cases, the diaphragm cracks, causing chambers *A* and *B* to become directly connected.

WHISTLE GIVES ONE LONG BLAST.

15. If, in transmitting a signal, the whistle simply gives one long blast, it may be due either to the reductions being made too close together, or to the diaphragm stem *10* of the signal valve working stiffly in the bushing *9*, in which event the passage at *e* would remain open until a sufficient difference of pressure existed in chambers *A* and *B* to force the stem *10* to its seat.

WHISTLE BLOWS WHEN BRAKES ARE RELEASED.

16. If the whistle blows every time the brakes are released, it indicates that there is direct connection between the main reservoir and signal pipe, and that the latter is charged to main-reservoir pressure. This may be due either to valve *4* of the reducing valve being held open by dirt on its seat, or to there being too much tension in the spring *9*; or, in the old-style reducing valve, Fig. 4, to the spring *10* being broken or too short, so that it does not force valve *4* to its seat.

The reason why the whistle blows when the brakes are released is as follows: Since there is a direct opening between the signal pipe and the main reservoir, air will flow from the former to the latter every time the main-reservoir pressure is reduced in releasing the brakes. This causes a reduction of signal-pipe pressure right at the signal valve, which, if the opening through the reducing valve is large enough, and the main-reservoir pressure is reduced sufficiently fast, will operate the signal valve and cause the whistle to give a blast. If the opening through the reducing valve is small, the whistle

may not sound if the signal pipe is long, whereas it may do so on a very short train or on a lone engine.

Main-reservoir pressure in the signal pipe can be detected from the train by a stronger discharge of air from the discharge valve when the signal cord is pulled; on the engine it will be indicated by the signal whistle screeching, due to the fact that the bell of the whistle is adjusted for 40 pounds pressure and not for 90.

OTHER DEFECTS.

17. Sometimes the whistle only gives a *weak blast* when the cord is pulled. This may be due to the regulating spring of the reducing valve being too weak, so that there is less than 40 pounds in the signal pipe; the whistle may be full of dirt or be improperly adjusted; or the passage through the bushing *7* in the signal valve, Fig. 7, may be partly stopped up with oil and dirt.

The bell of the signal whistle, Fig. 3, may be adjusted by loosening the locknut *n* and unscrewing or screwing up the bell, as the case may require.

If, in the signal valve, Fig. 7, the valve formed by the end of the stem *10* leaks or is held from its seat on bushing *7* by dirt, there will be a constant blow at the whistle that will produce a singing noise.

A *leaky* car discharge valve, due either to dirt on the seat of the valve or to a defective valve seat, is a common source of trouble. If dirt on the valve seat is the cause of the leak, opening and closing the valve will sometimes remedy it by blowing the dirt off.

The accuracy with which signals can be transmitted depends, to a considerable extent, on the fit of the stem *10* in the bushing *9*. If it makes too tight a fit, the whistle will give one long blast instead of the usual short ones, as already explained. Also, signal-pipe leakage is liable to operate the signal valve and cause the whistle to sound a blast, and the signal valve will not respond to a short, quick reduction.

If the fit of the stem is too loose, the signal valve will not be affected by leaks; neither will it respond to a light, quick

reduction in signal pressure. Also, when the train is short, the signal valve will respond to a reduction made on any of the cars in the train, but, on a long train, a reduction from the rear cars may not be sufficiently rapid at the signal valve to operate the valve, and the whistle will not sound. Then, again, the whistle is liable to give two or three blasts when the cord is pulled, if the stem is too loose. This is brought about as follows: When this cord is pulled, a reduction is made in the signal valve above the diaphragm, which causes the diaphragm to be raised, thus allowing air to escape from chamber *B* (below the diaphragm) to the whistle, causing it to give a blast. The reducing valve being opened by same reduction, admits air into signal pipe and chamber *A*, causing the valve to seat in bushing *7* before pressures above and below diaphragm equalize. When the stem fits properly, the pressure in the chamber above the diaphragm increases much faster than that in the chamber below it; hence, the diaphragm is held down and a second blast does not occur. When the stem fits loosely, however, both chambers charge at more nearly the same rate, and, the diaphragm being in a state of vibration, the rapid increase of pressure below the diaphragm will cause it to rebound, as it were, thus raising the stem and causing the signal whistle to give a second blast. In case the signal whistle gives two blasts when the cord is pulled, it can be remedied by lowering the stem *10* in the bushing *9*. The length of fit of the stem in its bushing should never be less than $\frac{1}{32}$ inch, nor more than $\frac{1}{16}$ inch, measuring from the top of groove *f* to the top of bushing *9*.

TERMINAL TEST OF AIR-SIGNAL APPARATUS.

18. In making up a train, the air-signal hose should be connected up at the same time the train-line hose is, and all the signal-line cocks opened except the rear cock on the last car of the train; this should be closed, and the signal hose hung up properly. While looking the train over for leaks, the signal hose and couplings and also the car discharge valves should be inspected to see if they are in good condition. If a discharge valve is found to be leaking, jerk it open a few times; if this

does not remedy the leak, the valve will have to be reseated with a new gasket. If a discharge valve is found to be defective while on the road, it should be cut out by closing the cutout cock in the branch pipe. The conductor should then be notified, and he should report the same for repairs at the end of the run. In testing the signal system, signals should be transmitted from the rear car of the train, from a car in the center, and also from the car next to the engine.

TESTING DEVICE.

19. The device about to be described has been used very successfully in testing for, and locating, defects in the signaling apparatus, and it ought to be more widely used than it is. It consists simply of an air gauge, a single-line hose, and a small petcock, the cock having a $\frac{1}{8}$-inch hole through its plug. The hose is fitted with a coupling, but has no nipple, the air gauge being connected to its nipple end. A hole is drilled through the coupling into the air space and tapped, and the petcock screwed into it.

When this device is coupled into the signal pipe, the signal-pipe pressure will be indicated by the air gauge, while, by means of the petcock, a reduction of any amount or duration may be made in the signal-pipe pressure.

20. Using the Device.—The **testing device** may be used to determine the condition of the automatic reducing valve, as follows: First connect the device into the signal pipe and charge the latter to standard pressure; then open the petcock wide, make a 10-pound reduction, and note the time required to raise the pressure to standard again. If the pressure rises slowly and the reducing valve is of the improved type, the passage through the valve is probably reduced by gum and dirt, and the valve should be thoroughly cleaned. If the reducing valve is of the old style, it may be that the supply valve does not open sufficiently to admit of its feeding faster, and the valve should be taken down and repaired.

To test the signal valve make a slow, gradual reduction of about the same magnitude as the leaks in the signal pipe would

amount to; then gradually increase the rate of discharge until the signal whistle blows. If the whistle blows when a slow, gradual reduction is being made, it indicates that the stem *10* makes too tight a fit in the bushing *9*, and that the pressure on the under side of the diaphragm cannot escape as the pressure above is reduced. The consequence is that the pressure in chamber *B* raises the diaphragm as soon as a sufficient difference of pressure is established between the chambers on either side of the diaphragm, and air discharges into the whistle, causing it to sound. If the whistle blows when a quick, heavy reduction is made, but will not do so with a quick, light reduction, the indications are that the stem *10* fits too loosely in the bushing *9*.

THE HIGH-SPEED BRAKE.

HIGH-SPEED SERVICE.

21. It is the *average* speed of a train between terminals that determines the service to which the train belongs. A high-speed train is one that makes a high average speed; hence the conditions of its operation must necessarily differ very materially from those of an ordinary express train. The express train may make an average speed of 35 to 40 miles an hour, while the average speed of the high-speed train may be 60 miles or more. The express train may attain a maximum speed for a short distance that is considerably greater than that attained by the high-speed train, but certain parts of the run that are comparatively safe are chosen for these bursts of speed. The high-speed train, on the other hand, must maintain a high rate of speed throughout the run, regardless of whether passing through yards or over bridges, switches, etc., so that the chances of having to make emergency applications of the brake are much greater than in ordinary service. Also, it is much harder to stop a train when traveling at high speed, and a greater distance is necessary in which to do so.

It has been found that, under the same conditions, the distance required to stop a train traveling at the rate of 40 miles

an hour is about twice as great as when traveling 30 miles; at 50 miles an hour, between three and four times the distance is required; while at 60 miles, about five times the distance is necessary. Hence, since emergencies are more liable to occur with high speeds, and since the distance in which a train can be stopped increases very greatly with its speed, it has become imperative that a more powerful brake than the quick-action one be employed on trains in high-speed service; the present *high-speed brake* is the direct result of this necessity.

The Westinghouse-Galton experiments, made in England in 1878, and the more recent experiments of the Master Car Builders' Association of this country have demonstrated: (1) that the friction exerted between the wheel and the rail is practically constant at all speeds; (2) that the friction exerted between the brake shoe and the wheel is very much less at high than at low speeds, being only $\frac{1}{3}$ as great at a speed of 55 miles per hour as it is when the wheels are only just moving; (3) that on account of this reduction of frictional resistance at high speed, a considerably greater pressure can be applied to the brake shoe when the speed is high, without danger of sliding the wheels; and (4) that in order to make a brake shoe exert as great a retarding force at high as at low speeds, it must be subjected to a greater pressure at high speeds.

The high-speed brake was made to conform with all these requirements, since it provides a very high cylinder pressure when the brake is first applied in emergency, and gradually reduces the pressure until it is low enough at slow speeds to avoid sliding the wheels.

GENERAL ARRANGEMENT OF APPARATUS.

CHANGES NECESSARY IN CAR EQUIPMENT.

22. The general arrangement of the apparatus of the **high-speed brake** on an engine, tender, and passenger car, is shown in Fig. 8. It is here seen that the apparatus and its general arrangement is practically the same as that of the quick-action automatic brake, but that the former contains a few

pieces of apparatus not employed in the latter, these special pieces being shown heavily lined in the figure. For instance, the only difference in the equipment of a high-speed and a quick-action brake, as applied to a *passenger car*, is the addition, in the former, of an automatic reducing valve, together with sufficient pipe to connect it to the brake cylinder. Also, in the high-speed brake every wheel on the car is fitted with the brake.

A, Fig. 8, illustrates the use of a small *safety valve* that may be attached to extra cars not fitted with the regular automatic reducing valve when they are to be temporarily attached to high-speed brake trains. This valve is simply intended to temporarily take the place of an automatic reducing valve, and it should not be used as a permanent fixture.

CHANGES NECESSARY IN ENGINE EQUIPMENT.

23. General Remarks.—The chief changes necessary to transform the ordinary quick-action brake into a high-speed brake, are made in the engine equipment. In the first place, the engine-truck wheels, as well as the drivers, are supplied with brakes in the high-speed system, as, by so doing, a gain of about 10 per cent. in the braking power can be made; this is not usually done with the quick-action brake. It will be observed that the engine-truck brake cylinder is connected with a flexible hose connection to its branch pipe. This is necessary, since the cylinder is fastened rigidly to, and therefore turns with, the engine truck.

The engine is also supplied with a triple valve of special design that operates both the driver and engine-truck brakes, a cut-out cock in the branch pipe being necessary for the purpose of cutting out the valve in case of accident to driver brake. The engine-truck brake has a separate cut-out cock, so that it can be cut out without interfering with the driver brake. An automatic reducing valve is connected to the pipe that leads from the triple valve to the brake cylinders, thus performing the work of three separate reducing valves connected one to each brake cylinder.

In the tender equipment, a quick-action triple valve is used in place of the plain triple employed with the ordinary automatic tender brake, and an automatic reducing valve is attached to the tender cylinder. In order to attach the quick-action triple to the tender cylinder, it is necessary to use a special cylinder head, and, since the quick-action triple does not contain a cut-out cock, one must be placed in the branch pipe leading to it.

24. Duplex Governor.—The ordinary form of pump governor is replaced by a *duplex governor*, and the feed-valve attachment on the brake valve is replaced with a *pipe bracket* that enables a *duplex feed-valve attachment* to be used. Both the duplex governor and duplex feed-valve attachment really consist of two ordinary instruments combined for the sake of cheapness and convenience, and each duplex instrument could be replaced with two regular instruments of the same kind. Both governors of the duplex pump governor are connected with, and are therefore operated by, main-reservoir pressure, since the pipe g leads to the main-reservoir connection on the brake valve. The regulating spring of one is adjusted to just withstand a pressure of 90 pounds per square inch on the governor diaphragm; the regulating spring of the other is adjusted for a higher pressure—about 120 pounds per square inch. A cut-out cock is placed in the pipe to the low-pressure governor, so that if the engine is to be used with a high-speed brake, it can be closed, thus cutting out the low-pressure governor and allowing the high-pressure one to govern the air pump. The cut-out cock is closed when the handle stands at right angles to the pipe, and open when the handle is parallel with it. If the engine is used with the ordinary quick-action brake, the cut-out cock is opened and the pump is then governed by the low-pressure governor, as will be explained later.

25. Feed-Valve Attachment.—The two valves of the **duplex feed-valve attachment** are adjusted for different pressures. The regulating spring of one is adjusted to just withstand a train-pipe pressure of 70 pounds per square inch, while the spring of the other is adjusted to about 110 pounds. The mechanism of each valve is exactly like the

mechanism of the valve shown in Fig. 17, and explained in connection with the F-6 brake valve in Part 1. The feed-valves are secured to the body of the reversing cock, and the passage *i* of each is connected with the pipe *b* by means of a chamber in the reversing cock. Also, the passage *f''* of both valves is connected with the pipe *a* by means of another chamber, and the cock is so constructed that the right-hand feed-valve can be cut out of, or into, service by means of the handle *h*. When the engine is coupled to a train equipped with ordinary quick-action brakes, the feed valve that is adjusted to 70 pounds is used, and the other one is cut out. When the engine is coupled to a train equipped with the high-speed brake, the high-pressure feed valve is cut into service.

There are two positions in which the handle *h* of the reversing cock may stand. The one shown is the position used when the engine is to be coupled to a train having the ordinary quick-action brake. In this position, the feed-valve that is adjusted for 110 pounds is cut out, and the train-line pressure is regulated to 70 pounds per square inch by means of the other feed-valve. If the engine is to be coupled to a high-speed brake system, the handle of the reversing cock is moved around to the right into the second position. This cuts into service the feed-valve that is adjusted for 110 pounds, and the train-pipe pressure is then regulated to that amount. This duplex feed-valve is usually placed under the running board of the engine.

OPERATION OF APPARATUS.

AUTOMATIC REDUCING VALVE.

26. Description.—In Fig. 9 are given various sectional views of the **automatic reducing valve,** (*a*) representing a side view with half of the valve removed, while (*b*) is a horizontal cross-section taken through the slide valve, and viewed from above; (*c*), (*d*), and (*e*) are rear views with the back portion of the upper half of the valve broken away so as to show in section the reducing-valve piston and slide valve, the section of the slide valve being taken through port *b*.

Referring to the figure, *B* is the bracket by means of which the valve is attached to the car or engine; *2*, the valve body; *3*, the spring box; *4*, the reducing-valve piston; *5*, the piston packing-ring; *6*, the piston stem; *7*, the piston-stem nut; *8*, the slide valve; *9*, the slide-valve spring; *10*, the cap nut; *11*, the regulating spring; *12*, the regulating nut and guide for piston *4*; *13*, the check-nut; *14*, a union stud; *15–16*, a union connection; and *17*, the strainer. The pipe to the brake cylinder connects with the valve at *X*, while the exhaust port *Y* leads to the atmosphere. Since the brake cylinder is connected at *X*, it is evident that the space within bushing *d* is always charged to the same pressure as the brake cylinder; hence, the slide valve *8* and the upper side of piston *4* are at all times subjected to brake-cylinder pressure also. A port *c*, views (*a*) and (*b*), passes through the slide valve from one side to the other; also, a triangular port *b* leads from port *c* to the face of the slide valve. A small port *a* passes through the seat of the slide valve and connects with the exhaust *Y*. In views (*c*), (*d*), and (*e*), the covered part of port *a* is represented by dotted lines.

When the valve is used on a car, the regulating spring *11* is adjusted to just withstand a pressure of 60 pounds per square inch on the piston *4*; when used on an engine, it is adjusted to withstand 50 pounds pressure.

27. Operation of Valve.—Views (*a*) and (*c*) show the position of port *a*, with respect to port *b* of the slide valve, for all pressures under that for which the regulating spring is adjusted, which is usually 60 pounds. Port *a* is, of course, stationary; the slide valve *8*, however, fits in between the shoulders of the piston stem *6*, and is operated thereby; hence, port *b* moves up and down with the piston.

As long as the cylinder pressure remains less than 60 pounds per square inch, the reducing valve plays no part in an ordinary *service application* of the brake, the valve remaining in its normal position, with port *a* blanked, views (*a*) and (*c*). Suppose, though, that in making a service application, the brake-cylinder pressure should increase above 60 pounds; in that event, the pressure above the piston *4* would be sufficient to

(d)

9. *Service; Pressure Exceeding 60 Pounds*

FIG. 10.

compress the regulating spring, and the piston and slide valve would be forced downwards until ports *a* and *b* assumed the position shown in view (*d*). In this position, brake-cylinder air is free to flow to the atmosphere through the ports *c*, *b*, and *a*, until the pressure is reduced to 60 pounds, when the regulating spring forces the piston and slide valve upwards into their normal position again. View (*d*) therefore shows the relative positions of ports *a* and *b* in a service application during the time the brake-cylinder pressure exceeds 60 pounds. The area of the opening through ports *a* and *b* in this position is such that air can discharge from the cylinder as fast as it enters through the service port in the slide valve of the triple.

The relative positions of ports *a* and *b* in an *emergency application* of the brake is shown in view (*e*). Here, air enters the brake cylinder from the train line and auxiliary reservoir in much greater volume than it could possibly escape through the ports *a* and *b* of the reducing valve; hence, piston *4* of the latter is forced downwards the full length of its stroke, and assumes the position shown in view (*e*). In this position, the passage through ports *a* and *b* is small, and air discharges quite slowly from the cylinder. As the pressure in the cylinder, and consequently above piston *4*, gradually decreases, due to the discharge through ports *a* and *b*, the regulating spring gradually raises the piston and slide valve, and, as the slide valve is raised, the opening through ports *a* and *b* gradually increases; consequently, the discharge from the cylinder increases accordingly until the brake-cylinder pressure is reduced to a safe amount (60 pounds), when the reducing valve assumes its normal position, covering the opening *a* so that no more air can escape from the brake cylinder.

IMPROVED AUTOMATIC REDUCING VALVE.

28. The latest form of the *high-speed* automatic reducing valve is shown in Fig. 10. This is an improvement on the valve just described, the changes, however, not being very great. In the old-style valve, Fig. 9, it will be noticed that the piston *4*, when in its normal position, is intended to make an air-tight joint with the bushing at *e*, the piston and bushing being

beveled for that purpose. In the new valve, the piston *4* includes a leather washer *e*, which forms an air-tight joint with the projection on the bushing. Also, the stem *6* has been shortened, and the guide *12* of the old valve is replaced in this valve by the spring abutment *22*. The operation of this valve is exactly the same as that of the old-style valve.

SAFETY VALVE.

29. In cases where a car equipped with an automatic brake must be used in connection with high-speed brakes, and there is not sufficient time in which to equip it with a regular automatic reducing valve, a small safety valve is screwed into the oil hole in the brake-cylinder head and used as a substitute during the trip. A sectional view of this **safety valve** is shown in Fig. 11. It consists simply of the valve body *2*, the valve *3*, regulating spring *4*, adjusting nut *5*, and lock cap *6*. The end *X* is screwed into the oil hole in the cylinder head, and, consequently, that portion of the valve marked *a* is always subjected to brake-cylinder pressure. Ports *y*, *y* connect the chamber above valve *3* with the atmosphere.

The spring *4* is adjusted by means of the nut *5* until it resists from 50 to 60 pounds pressure per square inch on the valve *3*. In adjusting either the safety valve or the automatic reducing valve, a gauge is attached to the brake cylinder, and the tension of the regulating spring is then adjusted until the gauge shows that the valve just retains the proper brake-cylinder pressure.

FIG. 11.

The operation of the safety valve is as follows: As is the case with the automatic reducing valve, the safety valve remains in its normal position as long as the brake-cylinder pressure

FIG. 12.

2308

FIG 13.

2363

is less than that for which the valve is set to operate. If, however, the pressure in the brake cylinder exceeds that to which the spring *4* is adjusted, the valve *3* will be forced upwards, compressing the spring *4*, and the brake-cylinder pressure will exhaust to the atmosphere through the valve *3* and exhaust ports *y*, *y* until it is reduced to the pressure for which the valve is set; the spring *4* will then force valve *3* to its seat and the remaining pressure will be retained in the cylinder. As this is not a very reliable form of valve, it should only be employed temporarily in cases where the other form cannot be obtained.

DUPLEX PUMP-GOVERNOR.

30. A sectional view of the **duplex pump-governor** is shown in Fig. 12. By comparing Fig. 12 with Fig. 3 of Part 1, it will be seen that both the diaphragm bodies and the steam-valve body of the duplex governor are exactly the same as the corresponding parts of the ordinary governor (improved type). The only difference in the two governors is that the duplex governor is provided with the *Siamese* fitting *S*, and an extra diaphragm case. This governor is nothing more than a combination of two diaphragm bodies with one steam valve body, and it operates in exactly the same way as the ordinary governor, only one of the diaphragms acting at one time. The description of the improved governor, Art. **27**, Part 1, applies to this governor also, and therefore no further description is necessary. It will be observed that in breaking away the steam-valve case in the illustration of this governor, a sufficient portion has been retained to allow the drip-pipe connection *36* to be shown. Also, in breaking away the right-hand diaphragm case, part of the union fitting *z* has been left in. The parts of the valve are lettered and numbered the same as the corresponding parts of the valve shown in Fig. 3, Part 1.

HIGH-SPEED BRAKE TRIPLE VALVE.

31. Ordinary quick-action triple valves are used on the cars of a high-speed train. The plain triple used on the tender with the quick-action brake, however, is replaced in the

high-speed brake by a quick-action triple, while the plain triple used on the engine is replaced by another plain triple of special design. The engine triple, it will be remembered, operates both the driver and engine-truck brakes; hence, it is necessary to use a triple designed especially for that purpose. Such a one is illustrated in Fig. 13. By comparing Fig. 13 with Fig. 7 of Part 1, it will be seen that practically the only difference between this triple and the ordinary plain triple is in the size of the ports; the operation of the two valves is exactly the same. The corresponding parts of both triples are lettered and numbered similarly.

SPECIAL CYLINDER HEAD.

32. In order to use a quick-action triple on the tender-brake cylinder, it is necessary to replace the plain cylinder head

Fig. 14.

with one like that shown in Fig. 14. The triple is secured to the part *T* in such a way that the port *d* of the triple, Fig. 9, Part 1, connects with the passage *P* in the cylinder head,

while port *Y* connects (through the large central hole) with the space within *T*. The two tap bolts *s*, *s* serve as plugs for the two ports that lead to the space within *T*, and the pipe that leads from the auxiliary reservoir is screwed into either one or the other of the ports, as required. Air passes out from the triple and enters the cylinder head at *P* and passes on up through the interior of *P′ P″* and so on into the brake cylinder. The automatic reducing valve is screwed into the cylinder head at *r*; *r′* is the cylinder oil plug.

FEED-VALVE PIPE BRACKET.

33. In order to use the duplex feed valve along with the F-6 brake valve, it is necessary to remove the original feed-

FIG. 15.

valve attachment and put a **feed-valve pipe bracket** in its place. A sectional view of this bracket, connected to the brake valve, is shown in Fig. 15. This figure represents

the same section of the F-6 brake valve as is given in view (*e*) of Fig. 16, Part 1.

The two pipes *a* and *b*, Fig. 8, that lead to the duplex feed-valve, screw into the pipe bracket *3* at *a* and *b*, Fig. 15. Thus, when the brake valve is in running position, air on its way to the train pipe flows through the passage *f′f″* and the pipe *a*, thence through whichever feed-valve happens to be cut in, and back through the pipe *b* and the passages *i* and *l* to the train pipe.

OPERATING THE BRAKE.

MAKING THE REDUCTIONS.

34. The brake on a high-speed train is operated in precisely the same manner as the ordinary quick-action brake. A number of reductions are made in a service stop, as with the latter, and the brake will be set in full or at about its maximum pressure when a reduction of from 20 to 22 pounds is made in the train-pipe pressure, if the piston travel is adjusted to 8 inches. In the high-speed system, the train pipe and auxiliaries are charged to about 110 pounds pressure per square inch, so that the brake may be applied three times in full, and still have the same pressure for the fourth application as would be had for the second application of the quick-action brake. That is, if train-pipe pressure is reduced from 110 to 90 pounds, sufficient air will pass from the auxiliary reservoir to the brake cylinder to raise its pressure to about 50 pounds. If, now, the brake is released without recharging at all, and the train-pipe pressure is reduced from 90 to 70 pounds, the brake will again be set with a pressure of 50 pounds. A second release, and a reduction from 70 to 50 pounds, will set the brake for the third time with a 50-pound pressure, and the train pipe and auxiliary will stand equal at 50 pounds. With the quick-action brake, a 20-pound reduction from 70 pounds train pipe will apply the brake with 50 pounds pressure, and the train pipe and auxiliary will stand equal at 50 pounds also. In fact, with either brake, a 20-pound reduction from a pressure of 70 pounds or more will apply the brake with a pressure of 50 pounds per square inch.

With no leakage, a 22-pound reduction would set the brake with about 60 pounds pressure; hence, if a greater reduction is made, air will simply be wasted, since the reducing valve will not allow over 60 pounds pressure to remain in the brake cylinder.

With a 30-pound service reduction and an 8-inch piston travel, the auxiliary and brake cylinder would equalize at about 80 pounds per square inch were the reducing valve inoperative; while, in an emergency application, they would equalize at about 85 pounds per square inch, on account of some air passing from the train pipe into the brake cylinder. In an emergency application, however, the reducing valve gradually reduces the brake-cylinder pressure from 85 pounds to 60 pounds. The effect that this extra pressure, when the brake is first applied, has on the braking power of a train, was brought out by a system of experiments conducted by the Pennsylvania Railroad. These experiments proved conclusively that, at a speed of 60 miles per hour, an emergency application of the high-speed brake will stop a train in 450 feet less space than the ordinary quick-action brake.

BRAKE TESTS.

35. The tests referred to were made on October 1 and 2, 1894, near Ship Road, Pennsylvania, on a descending grade of 29 feet to the mile, the weather being fair and the rails dry. The train was made up of a locomotive and six Pennsylvania Railroad passenger cars, the total weight of the train being 564,000 pounds. The train was fitted throughout with the high-speed brake equipment before the test began, and no alterations were made during the test. The brakes were converted from ordinary quick action at 70 pounds to high speed at a much higher pressure, and back again, by simply cutting in the proper pump governor and feed-valve, so that the same apparatus was used in all the tests. A correct speed recorder was used for measuring and recording the speed of the train, and the brakes were applied at a certain spot by means of a trip arrangement (connected to the train pipe) coming in contact with an obstruction that was fastened to one of the

ties. This fixed the exact spot at which the brakes were applied, and enabled the length of the stop to be accurately measured.

The tests on the first day were made at a speed as near 45 miles per hour as possible, two tests being made with the ordinary quick-action automatic brake, and three with the high-speed brake cut in. The train-pipe pressure in the first two tests was 71 and 69 pounds, respectively, while in the last three tests it was 100, 104, and 100 pounds, respectively.

RESULTS OF BRAKE TESTS.

FIRST DAY.

Train-Pipe Pressure. Pounds.	Actual Speed in Miles per Hour.	Length of Stop in Feet.	Corresponding Length of Stop at 45 Miles per Hour.	Average Length of Stop at 45 Miles per Hour.
71	47¾	776	694	688
69	45½	697	683	
100	46¾	584	567	
104	46¼	610	580	567
100	47	601	555	

SECOND DAY.

Train-Pipe Pressure. Pounds.	Actual Speed in Miles per Hour.	Length of Stop in Feet.	Corresponding Length of Stop at 60 Miles per Hour.	Average Length of Stop at 60 Miles per Hour.
68	60¾	1,697	1,658	
71	61½	1,634	1,558	1,622
71	58¾	1,584	1,649	
100	61¼	1,372	1,319	
104	61½	1,361	1,299	1,296
105	61½	1,330	1,269	
108	58¼	1,125	1,189	1,172
109	64¼	1,202	1,155	

On the second day, the tests were made at a speed as near 60 miles per hour as possible, three tests being made with a train-pipe pressure of about 70 pounds, and five with a pressure of about 100 pounds. The observations taken during the tests are given in the preceding table.

Explanation of Table.—Column 1 gives the train-pipe pressure used in each test; column 2 gives the actual speed of the train at the time the emergency application took place; column 3, the actual distance in feet the train traveled after the emergency application was made; column 4, the distance in feet the train would have traveled had it been running at the speed indicated (45 the first day, 60 the second), instead of at the actual speed as given in column 2; column 5 gives the averages of the distances marked with brackets in column 4.

From column 5 it will be seen that, at a speed of 45 miles per hour, the high-speed brakes will stop a train in about 120 feet less space than the ordinary quick-action brake, while, at 60 miles per hour, it will stop the train in about 450 or 326 feet less distance, depending on whether the train-line pressure used is greater or less than 105 pounds.

CONTROL OF HEAVY FREIGHT TRAINS ON GRADES.

36. The question of **adequate brake power for trains** on grades is an important one, especially when the operation of heavily loaded trains of large-capacity cars is considered. On medium grades, the quick-action brake has been found quite effective in both passenger and ordinary freight service, but, on very steep grades, it is extremely difficult and quite risky to attempt to control heavily loaded freight trains by means of the quick-action brake alone and without the aid of some special devices by means of which the braking power can be increased when necessary, to conform more nearly to the load.

The Westinghouse Air Brake Company has invented a very simple and satisfactory method of improving the brake control of heavily loaded trains, which, while allowing the train to be

worked ordinarily at the standard train-line pressure, provides for a higher pressure when circumstances require it. The method necessitates no change in the ordinary quick-action car apparatus, all the changes necessary being made in the engine equipment.

WESTINGHOUSE SPECIAL APPARATUS.

GENERAL ARRANGEMENT.

37. This **special brake apparatus** and its arrangement on the engine and tender is shown in Fig. 16. It will be seen to differ from the ordinary equipment in that (1) the pump governor is replaced by a *duplex governor;* (2) the feed-valve attachment by a *duplex feed-valve;* and (3) the engine triple valve by a *special high-speed triple.* The latter is necessary, since the engine-truck wheels, as well as the driving wheels, are fitted with brakes. Also, a safety valve, like that shown in Fig. 11, Art. **29**, is connected to the engine and tender-brake cylinders to prevent the cylinder pressure from increasing above 50 pounds per square inch, as it is not considered desirable to increase the pressure in either cylinder above that amount.

The duplex feed-valve is exactly the same as that used in connection with the high-speed brake, and is attached to the brake valve in the same manner. One feed-valve is adjusted for 70 pounds, while the other is usually adjusted for 90 pounds.

The duplex pump-governor, also, is the same as the one used with the high-speed brake, but it is piped differently, as will be seen by comparing Figs. 8 and 16. In the high-speed brake, both diaphragm cases of the governor are piped to the engineer's brake valve at *R*, while in Fig. 16, only the right-hand diaphragm case is piped to *R*, the other case being piped to a connection in the reversing cock, which leads to the chamber that communicates with the passage *f''* and chamber *u* of the feed-valve, Fig. 17. Pipes *c* and *a* therefore connect with the same chamber in the reversing cock. By this arrangement of the piping, it is possible: (1) to regulate the train-pipe pressure to 70 pounds and the main-reservoir pressure to 90 as

ENGINE TRUCK
BRAKE CYLINDER

FIG. 16.

long as the brake valve is left in running position, and when the brake valve is moved to lap position, to pump up main-reservoir pressure to 110 pounds; or (2) to continuously regulate the train-pipe pressure to 90 pounds and main-reservoir pressure to 110 pounds.

OPERATION OF APPARATUS.

38. Ordinary Running Conditions.—Ordinarily, the handle of the pump-governor cut-out cock is turned parallel with the pipe, so that the left-hand side of the governor operates the air pump. The reversing-cock handle is also turned to the left, as shown in Fig. 16, so that the train-line pressure is regulated by the left-hand feed-valve. Now, suppose the brake valve to be in running position and the pump working; air from the main reservoir can pass through the brake valve and pipe *a* to chamber *u* of the left-hand feed-valve, Fig. 17, and thence through pipe *c* to the pump governor. As soon as main-reservoir pressure is raised to 90 pounds, the governor will stop the pump. Main-reservoir pressure will then be maintained at 90 and train-pipe pressure at 70 pounds, as long as the brake valve is carried in running position.

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If a reduction in train-pipe pressure is made and the brake valve is then lapped, the supply valve *63* of the feed-valve will be forced from its seat by the regulating spring, and the air in

Fig. 17.

pipe *c* will consequently be reduced to train-pipe pressure. Now, since no air can pass from the main reservoir through the brake valve into pipe *c*, the pressure in the pipe must remain less than 90 pounds as long as the brake valve is lapped; hence, the low-pressure side of the pump governor is cut out of service just as effectually as though the cut-out cock in pipe *c* had been closed. The pump, therefore, will operate until 110 pounds pressure is accumulated in the main reservoir, when it will be stopped by the high-pressure side of the pump governor. With 110 pounds in the main reservoir with which to release the brakes, a quick release and prompt recharging of the auxiliaries is assured.

39. Descending Long Grades.—When the train is to descend a long grade, however, the cut-out cock in the pipe *c* is turned at right angles to the pipe, so as to cut the low-pressure side of the pump governor out of service, and the handle of the reversing cock is turned in the opposite direction to that shown in the figure, thus cutting into service the feed-valve that is adjusted to 90 pounds. Thus, when descending long grades, the main reservoir is charged to 110 and the train pipe to 90 pounds.

The brakes are operated in exactly the same manner as the quick-action brake, the only difference being that with the auxiliaries charged to 90 pounds, a full-service application of the brakes will result in a brake-cylinder pressure of about 65 pounds per square inch instead of 50 pounds.

When grades are exceptionally long and heavy, so that the driver brakes have to be held on hard for a considerable length of time, trouble is generally experienced with the driving-wheel tires heating, the friction between the brake shoe and the wheel generating heat that expands the tire. On such grades, therefore, the brake known as the *water brake* can be used to good advantage.

THE WATER BRAKE.

PRINCIPLES INVOLVED.

40. If the valve gear of a locomotive is reversed while the locomotive is running forwards with throttle closed, the engine cylinders will be converted into air compressors. As the piston moves either forwards or backwards, a vacuum is created in the cylinder behind it and hot gases from the smokebox are drawn in to fill the vacuum. The gases in the cylinder ahead of the piston are compressed, and offer a resistance that acts to stop the movement of the piston, and thus the speed of the engine is retarded.

With the valve gear in the reverse direction to which the engine is running, therefore, the engine cylinders act as brakes to retard the speed of the train. If the air drawn into the cylinders were cool and free from cinders, this method of braking would be simple and very efficient for use on engines on long down grades. As it is, however, cinders would be drawn into the cylinders and cause trouble; also, the gases in the smokebox are very hot, and, when drawn in, their temperature is still further increased by compression; hence, serious injury would result to the cylinders, valves, and valve seats, if this method of braking were used without some means of preventing the hot gases and cinders from entering the cylinders.

The water brake (sometimes spoken of as the LeChatelier brake) overcomes the objections to this method of braking by introducing wet steam at a low pressure into the cylinders, thereby excluding the hot gases. Unfortunately, the term "water brake" is a misnomer when applied to the LeChatelier method of braking, and is very liable to create the impression that water is used in the cylinders, whereas, in reality, the braking is done by means of low-pressure wet steam. It is scarcely necessary to remark that water in the cylinders has too often been the cause of considerable trouble for any one to voluntarily introduce it there.

CONSTRUCTION OF BRAKE.

41. The **water brake** was invented nearly fifty years ago by a prominent French engineer named LeChatelier, but it was not introduced in this country until years afterwards, being first used on the early mountain roads in the Rocky Mountains, a region where it has proved a very valuable auxiliary braking device. This brake is shown applied to an engine in Figs. 18 and 19, the former being a plan view of engine, and the latter a view taken at rear of cylinders. The brake apparatus consists of an ordinary globe valve *a* and sufficient piping *b b b* to connect the valve with the exhaust passages in the cylinder saddle at *c*, *c*. The globe valve is set in the boiler head, on a level with the crown sheet and at a point where it will be within easy reach of the engineer. The pipe used in connection with the globe valve is either a $\frac{3}{8}$-inch or a $\frac{1}{2}$-inch pipe, depending on the size of the engine cylinders. It divides into two branches at the cylinder saddle, each branch leading to, and opening into, one of the exhaust passages, as shown.

OPERATION OF PARTS.

42. As previously stated, the duty of the water brake is to supply low-pressure steam to the cylinders when the engine is running reversed, so that, by acting as compressors, the cylinders can be used as an auxiliary braking device without being injured by hot gases and cinders from the smokebox. It is well known that water will boil at 212° F. if in the open air; if subjected to a boiler pressure of, say, 180 pounds gauge, however, it will not boil until its temperature has been raised to about 380° F. If, now, some of the water in the boiler is allowed to escape into a pipe or vessel connected with the atmosphere, its temperature will be far greater than 212° F.; hence, it will boil and be converted into steam. The temperature of this steam, however, falling considerably during the conversion, the pressure exerted by it will be reduced accordingly.

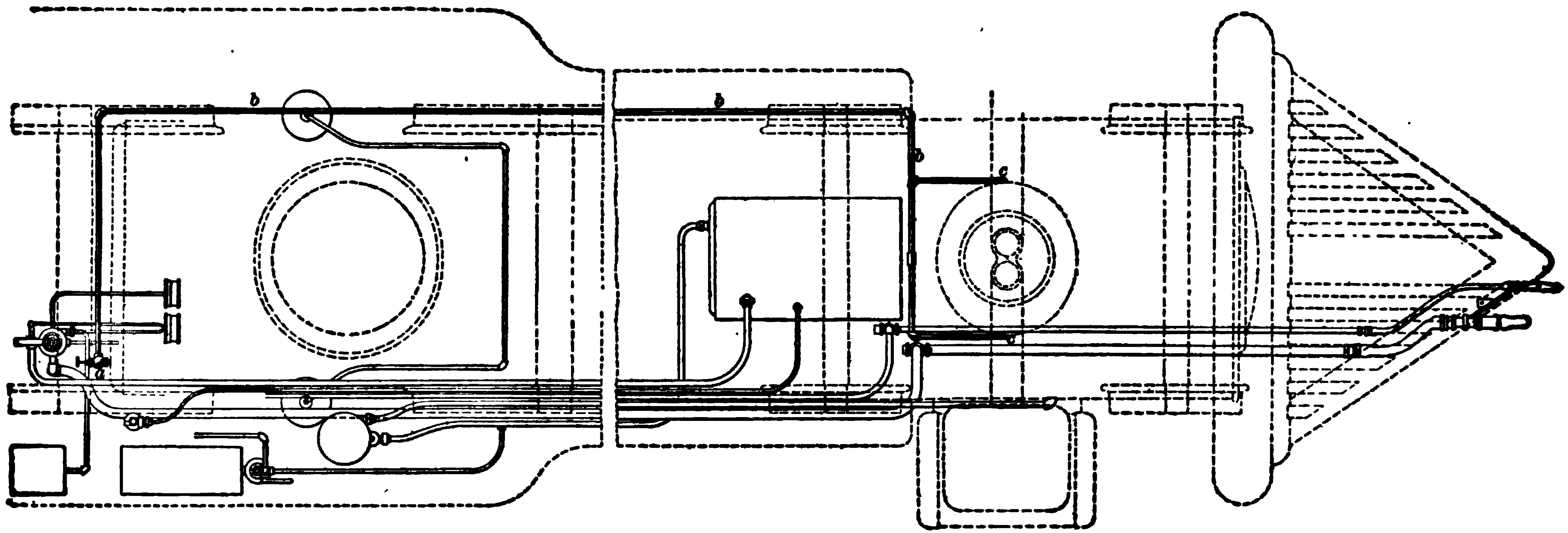


FIG. 18.

The valve and piping of the water brake simply provides the engineer with a convenient means of introducing water from the boiler into the exhaust passages in the cylinder saddle, where it is immediately converted into steam for use in the cylinders. By introducing the water into the exhaust passages,

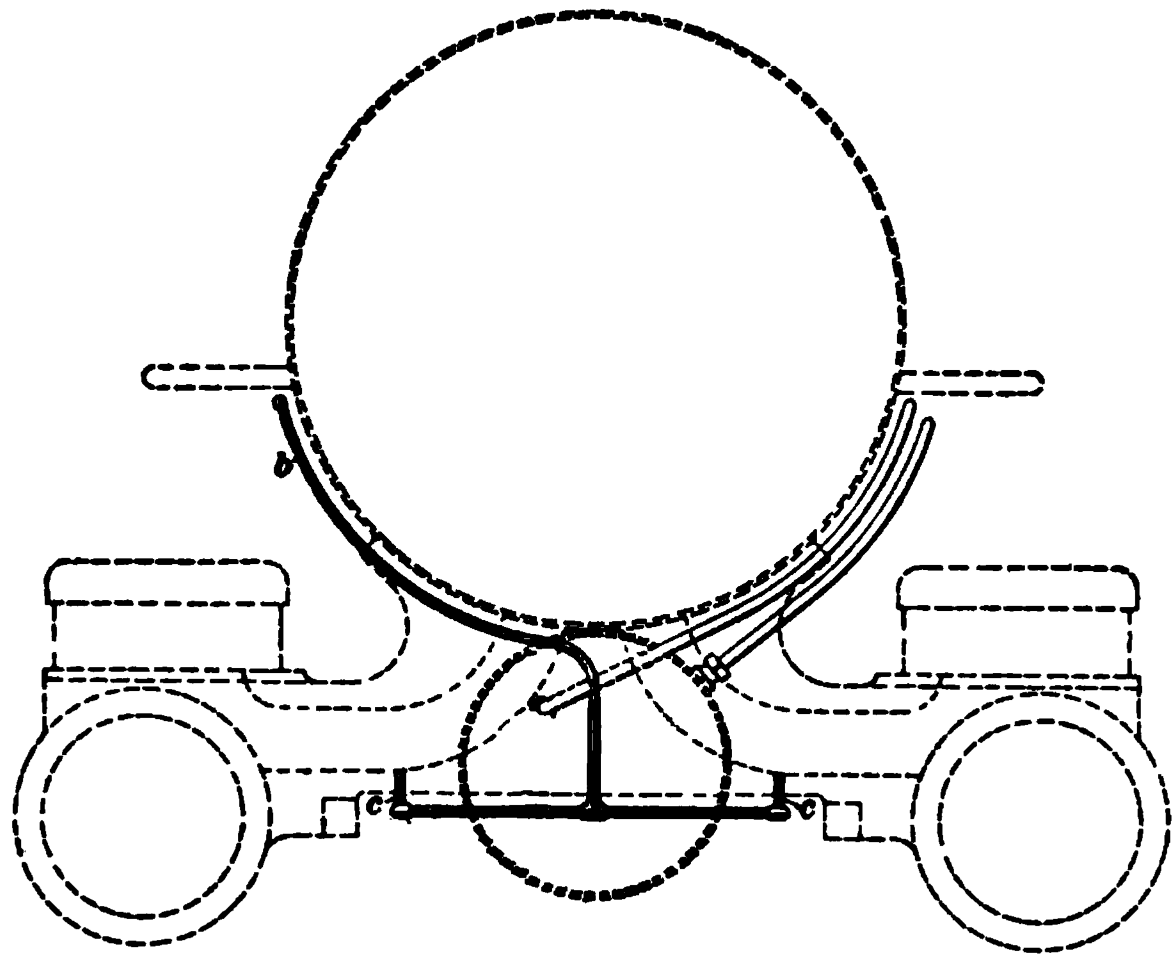


FIG. 19.

a vacuum is prevented from forming therein; hence, there is no tendency for the hot gases in the smokebox to be drawn into the cylinders.

It thus will be seen that the operation of this brake depends on the excess temperature of the water in the boiler over that required to boil water under atmospheric pressure; if the water in the boiler were at a temperature less than 212° F., it would not be converted into steam when discharged into the exhaust passages, and the result would probably be a broken cylinder head.

OPERATING THE BRAKE.

43. The water brake should always be operated in a **certain regular order,** which is as follows: First, be sure that all the cylinder cocks are open and that the throttle valve is shut; next, open the water valve (i. e., the globe valve *a*) about one-quarter turn; then immediately place the reverse

lever of the engine one or two notches back of the center and note the color of the steam issuing from the cylinder cocks. If dense white in color, the water valve is open sufficiently, but if the steam has a bluish color at the cylinder cock, which gradually changes to grayish white as its distance from the cock increases, the water valve should be opened a little wider until the steam has a dense white appearance from the moment it leaves the cylinder cocks. If the engine throws water from the stack, the valve is opened too wide and should be closed sufficiently to stop the trouble.

The amount of braking power exerted by the water brake depends on the position of the reverse lever. When it is in the first notch from the center, it exerts the least braking power, and the braking power is increased as the lever is moved towards the corner notch. The retardation of speed should therefore be regulated by placing the reverse lever in the notch required, and the water valve should not be changed after once being adjusted.

The water brake can be used when the engine is running either forward or backward, by simply placing the reverse lever so as to convert the cylinders into air compressors, observing the same rules of operation, regardless of the direction of running.

When it is desired to shut off the water brake, first close the water valve *a* and then *slowly* move the reverse lever towards the center, to avoid throwing water from the stack.

The water brake, it must be remembered, acts to stop the rotation of the drivers, so that if the air driver brake is used in conjunction with it, the braking force acting on the drivers will be too great, and they will be skidded. The water brake is simply an auxiliary braking device and should be used intelligently. It is most effective on a steady motion of from 3 to 12 miles per hour, is less effective at speeds greater than 12 miles per hour, and it should not be used at a greater speed than 18 miles per hour.

In double-heading on a grade, the engineer not operating the air brake assists in retarding the speed of the train by using the water brake to whatever extent advisable.

THE SWEENEY AIR COMPRESSOR.

PRINCIPLES OF WORKING.

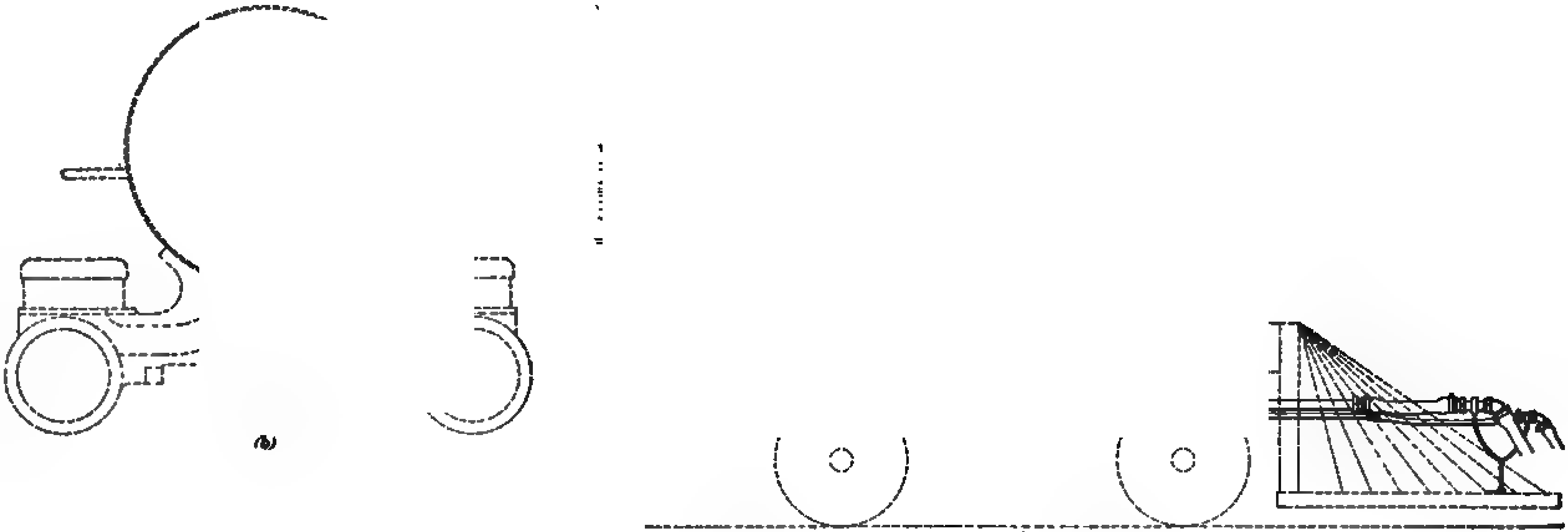
44. The *Sweeney air compressor*, or the "Sweeney," as it is commonly called, is an air-compressing device that is used quite extensively on Western roads where the grades are heavy. It is not intended to replace the ordinary air pump, but rather to act as an auxiliary compressing device to help out the pump. In case the pump becomes disabled, however, it may be made to supply the entire amount of air necessary to bring the train safely down the grade.

CONSTRUCTION OF COMPRESSOR.

45. Two views of the **Sweeney**, applied to an engine, are given in Fig. 20 (*a*) and (*b*). It will be seen that a 1¼-inch pipe is tapped into the top of the steam chest at *a*, and thence leads to the main reservoir. A stop-cock *c* is placed in the pipe so as to control the passage through it. This stop-cock can be opened and closed from the engine cab by means of the rod *e*, which is connected to the lever *b* of the stop-cock. Pushing the handle forwards opens the cock, while pulling it backwards closes it. Also, a check-valve *v* is placed in the pipe, close to the main reservoir. The object of this valve is to prevent pressure from flowing from the main reservoir back through the pipe to the steam chest. A safety valve *d* is also provided, which prevents the main reservoir from being overcharged, since it will open and allow the air to discharge from the cylinders to the atmosphere when main-reservoir pressure is raised to the pressure for which the safety valve is adjusted.

OPERATING THE COMPRESSOR.

46. To **operate** the Sweeney, the throttle must, of course, be closed, and the engine running. The cylinder cocks should first be left open while the drivers make two or three revolutions, so as to get rid of any water there may be in the



(b)

(a)

Fig. 20.

cylinders. The engineer's brake valve should then be placed on lap, the stop-cock *c* opened, and the engine reverse lever placed several inches back of the center notch, assuming the engine to be running forwards. By reversing the valve gear while the engine is running, the cylinders are converted into air compressors, and air is compressed and forced into the steam chest and thence through the 1¼-inch pipe to the main reservoir. As the capacity of the steam cylinders is large compared with that of the air-pump cylinder, the main reservoir is charged in a very short time by this method. The reverse lever must be left back of the center notch at least 15 seconds after the gauge indicates standard pressure.

To throw the Sweeney out of service, place the reverse lever in the forward motion and close the stop-cock *c*; care must always be taken to see that the stop-cock is closed before steam is used, since, if it is left open, the air-brake system will be charged with steam when the engine throttle is opened, and trouble will surely result.

CAR LIGHTING.

INTRODUCTORY REMARKS.

1. Among the many advances that have been made in railroad equipment during the last few years, one of the most notable has been in connection with the matter of **car lighting.** The ordinary oil lamp was never very satisfactory, its objectionable odor and heat, and its liability to explosion—to say nothing of its poor lighting qualities—emphasizing the necessity of producing something better. Hence, although on the majority of cars oil is still used, yet on the better class of trains, the railroad companies have for some years been adopting **gas,** and, in some cases, **electric light.**

The first step in the direction of improvement on the old oil-lamp system was the use of ordinary coal gas, stored at pressure and fed out gradually, but the illuminating power of this gas was impaired by compression. Now, however, **oil gas** is being widely used instead; it is stored at a high pressure and passes through a pressure regulator on its way to the lamps, thus having its pressure reduced to a proper degree. This gas is, in this country, made from a high-grade petroleum distillate, and in Europe from what is called *shale* oil. It has the property of enduring considerable compression without any loss in illuminating power, an advantage not shared by ordinary coal or "city" gas. This method of lighting by oil gas is safe, clean, and economical; the light itself is soft, and at the same time brilliant, and, being evenly distributed, renders reading in any part of the car a pleasure. The system almost exclusively used in this country is the *Pintsch,* and this is the one treated of in the present Section.

THE PINTSCH SYSTEM.

GENERAL DESCRIPTION.

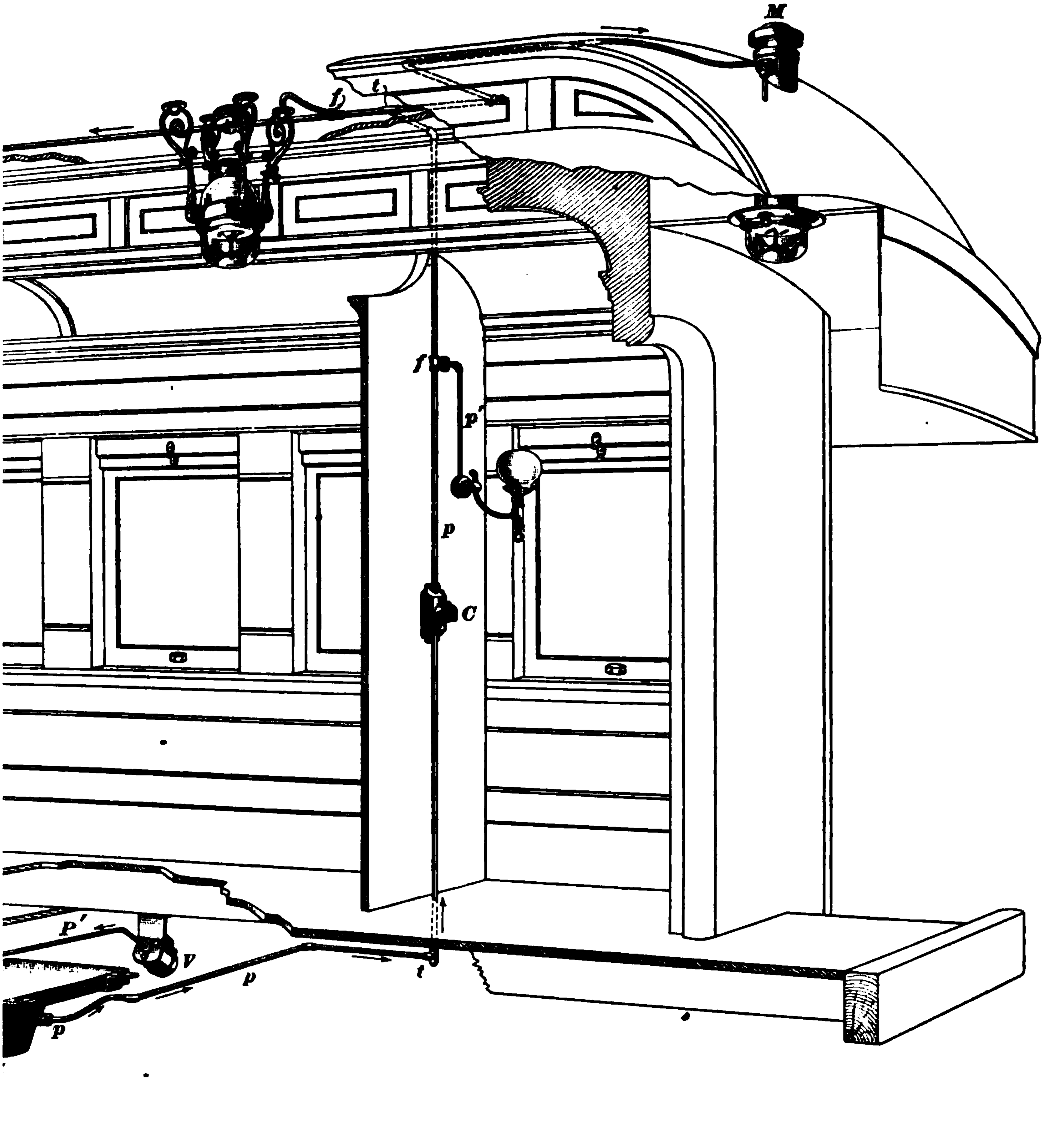
2. In the **Pintsch system**, the lamps are supplied with gas from storage tanks or holders carried underneath the car. The gas is stored therein at a pressure of about 150 pounds per square inch, and on its way to the lamps passes through a regulator that automatically reduces it to a pressure of about 1 ounce per square inch, irrespective of the actual pressure in the tanks. The supply of gas carried on a car varies according to the service it is engaged in, but, on an average, a supply of gas for from two to four nights' service is carried.

GENERAL EQUIPMENT.

3. The general arrangement of the apparatus is shown in Fig. 1, wherein H is the *gas holder* in which the gas is stored under pressure and from which it passes through pipe P'' to the *pressure regulator* R. Thence it goes through the pipes $p\,p$ to the piping on the roof of the car, being distributed thence to the various lamps.

When the holder H is about to be charged, a *hose* connecting with the charging lines from the gas station is attached to a *filling valve* V, one of these valves being located on each side of the car, for convenience. Pipes P and P' lead from the filling valves to the holder. When the charging is being effected through the valve on the far side of the car, as viewed in the figure, the gas comes through pipe P', and on through P'' into the holder. Afterwards, gas feeds back to the regulator through pipe P''. A *pressure gauge* G is piped to the **T**-flange union u. This gauge serves two purposes: *first*, to show what the pressure is in the holder and in the pipes P, P', and P'' (these, by the way, being spoken of as the *high-pressure* pipes); and *second*, to show how much gas is consumed in a given period.

About 5 feet above the car floor is placed the *main cock* C,


M
f
t
f
p'
p
C
P'
V
p
t
p

boxed in so as not to be tampered with. By means of this cock the brakeman can control the flow of gas to the lamps.

Above each lamp in the roof of the car is fixed a *ventilator*, that for the vestibule lamp being shown at *M*, and that for one of the aisle lamps, at *N*.

GAS HOLDER.

4. An illustration of the **gas holder**, also called a *receiver*, is given in Fig. 2. These holders are cylindrical in form and have dished ends for the sake of greater strength; a flat end would bulge out under pressure. The ends of the holders are either

FIG. 2.

riveted and bolted on, or, as in Fig. 2, brazed. A piece of angle iron *L* is bolted on to each end, and is itself bolted to the hanger that is attached to the car frame. At one end is the *outlet bushing b*, to which is attached a valve known as the *holder valve*.

These holders vary in capacity according to the service for which the car is intended. The sizes used on railroad cars are as follows:

SIZES OF GAS HOLDERS.

Diameter.	Length.		Capacity.
Inches.	Feet.	Inches.	Cubic Feet.
16½	6	1	8.8
18½	6	1	11.0
20½	6	1	13.5
20½	7	10	17.5
20½	[illegible]	6	19.0
20½	9	6	21.3

(a)

(b)

Fig. 4.

HOLDER VALVE.

5. There are two types of **holder valve** in present use, the "old style" and the "new style." The old style of valve is shown in Fig. 3, the new style in Fig. 4, (*a*) in each case being an elevation, and (*b*) a section. The new style differs from the old in that the flanges *F*, *F* on the gland *G* are dispensed with, the gland being made hexagonal at *H* and tightened up by means of a wrench, instead of using bolts, as in the old type.

6. Description of Parts.—The valve marked *v* controls the flow of gas into or out of the holder. To open or shut this valve, the cap *C* has to be taken off by means of key *K*, and the valve turned by key *k*. *g*, *g* are gaskets to make the various joints gas-tight. The dotted circle behind the valve *v* is the passage leading to the filler, the pipe connection being made by the union *u* shown in the elevation. There is one of these connections on each side of the valve, as seen in Fig. 1. The connection to the holder is made by means of the outlet bushing *b*, Fig. 2.

REGULATOR.

7. In Fig. 5 is given an outside view of the **regulator** used in the Pintsch system, *I* being the inlet and *O* the outlet. The *inlet bushing*, shown separately at (*a*) is screwed into the


(*a*)

FIG. 5.

regulator casting at *I*, the connection with the *high-pressure piping* being made by means of the fitting *F* shown in Fig. 6. The flange *f*, Fig. 6, is screwed on to the fitting *F*, and then this flange and the flange *f'*, Fig. 5, are bolted together by three

bolts. Connection is made at *O* with the low-pressure piping leading to the various lamps.

Fig. 6.

We do not show a section of these regulators, as they are supposed to be put up as received from the makers, and not to

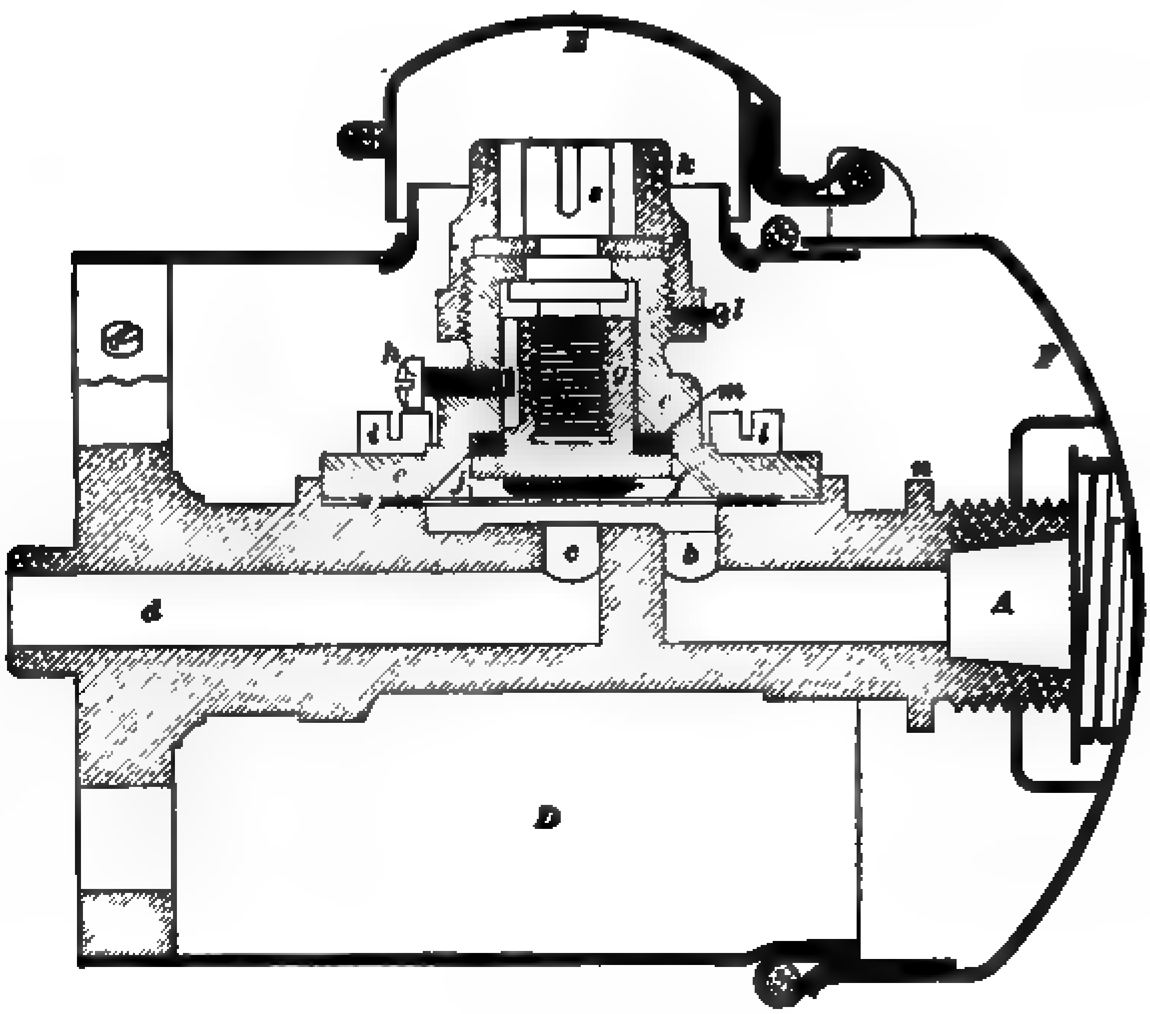


Fig. 7.

be opened subsequently. They are guaranteed for five years, and if found to be working improperly at any time, they will be replaced by the makers, free of charge, if returned to them unopened.

FILLING VALVE.

8. The **filling valve** used on the cars is shown in Fig. 7, a sectional view of the valve and its cover being there given. Gas is admitted from the main supply pipe through a hose connection made at *A*. The gas passes along the passage up through *b*, and if the valve *f* is off its seat, as shown in the figure, the gas passes down through *c* and along passage *d* into the pipe leading to the holder. The valve *f* is raised or lowered by turning the stem *s*. When the valve is raised off its seat to admit gas, it is screwed up against the bonnet *e e*, the packing ring *m* making the joint gas-tight. The valve carrier *g*, which moves up and down as the stem *s* is rotated, is prevented from turning around by the screw *h*, the end of which engages in a slot cut in *g*. The bonnet *e e* is bolted to the body of the filling valve by the screws *i*, the gasket *j* making the joint. The gland *k* is locked in position by the screw *l*. *D* is the cover enclosing the whole, *E* being the key cap and *F* the cover cap.

PRESSURE GAUGE.

9. The various **pressure gauges** used are shown in Fig. 8. (*a*) is the one shown in use in Fig. 1; (*b*) is similar, except for the method of attachment; (*c*) is the kind used by the car filler. In gauge (*a*), the type shown in Fig. 1 and also in Fig. 14, the pipe *P* leads to the T-flange union *u* in the piping between the filling valve and holder. The construction of the gauges is the same in each case. They are graduated to atmospheres, instead of pounds, as in the case of steam gauges; they can be had, however, graduated to both atmospheres and pounds. *Atmospheric pressure* is about 14.7 pounds per square inch (rather less than 14¾ pounds), so that a

"pressure of 8 atmospheres" is $14.7 \times 8 = 117.6$ pounds; 10 atmospheres is $14.7 \times 10 = 147$ pounds; 12 atmospheres is $14.7 \times 12 = 176.4$ pounds, and so on.

All gauges are carefully tested and adjusted by the Pintsch company before being sent out. They are compared with a

FIG. 8.

standard gauge at every atmosphere, from 1 to 12 inclusive, both ascending and descending, and any of them that show a total range of error of more than $\frac{1}{2}$ atmosphere are rejected.

MAIN COCK.

10. In Fig. 9 (*a*) is shown an outside view of the fitting known as the **main cock,** one of which is provided on each car. Its position in the car was shown in Fig. 1 at *C*; see also Fig. 20. This cock is boxed in and is provided with a key (*b*) by which the brakeman can turn the gas on and off from that particular car.

11. Double Pipe Line.—It is sometimes advisable, in the case of private cars, and also sleeping and dining cars, to run two separate lines of roof pipes, using two main cocks (see dotted parts C', C' in Fig. 20). The lamps in the main body of the car, and also those in the smoking and dining rooms, are connected to one of the pipe lines, while the passageway and toilet brackets, and the end lamps and vestibule lamps are connected to the other line. This enables the brakeman, by means of the main cock, to control the lamps on one line independent of the lamps on the other line. On postal cars, the main cock shown at (*c*) is used.

LAMPS.

DESCRIPTION OF VARIOUS TYPES.

12. Various designs of lamps are used in this system, as illustrated further on. The *lamp body* is practically the same in each case, however; it is illustrated in Fig. 10, which is a half-sectional view.

The glass *globe*, or *bowl*, is marked $A\,A$, $B\,B$ being the opalescent or opal *dome*. Gas from the supply pipe in the roof of the car passes down one of the arms supporting the lamp (see E', Fig. 24) and passes into the ring C at a, thence going up through tube b

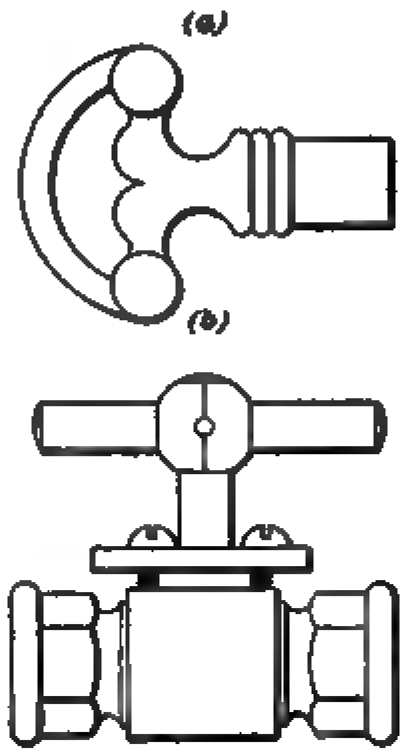
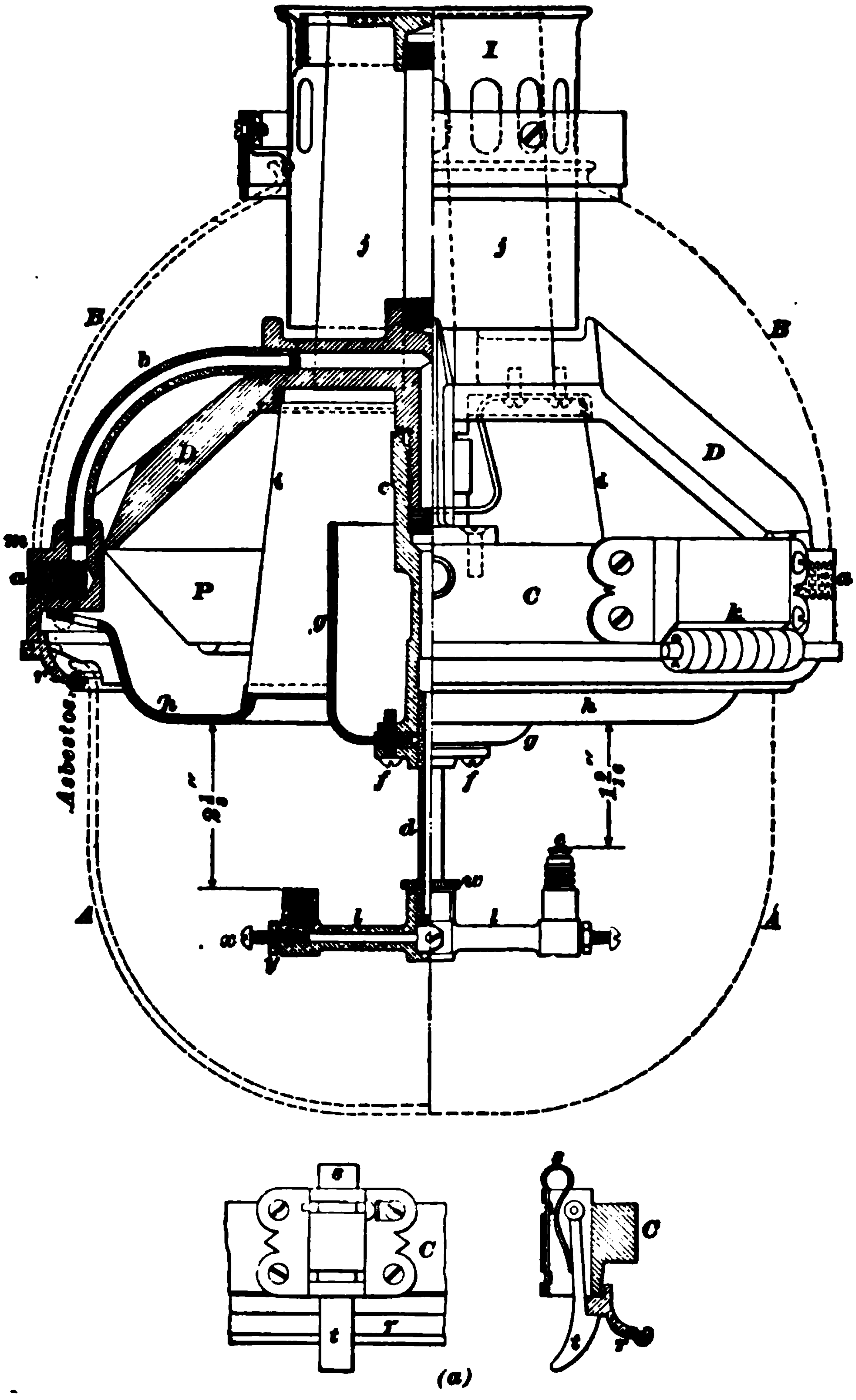


FIG. 9.

and down the pillar c and so to the *cluster stem* d, *cluster* $l\,l$, and *burners* e. The *cup reflector* $g\,g$ is bolted to the pillar c by screws f, asbestos rings being placed above and below the opening in reflector; $h\,h$ is the *ring reflector;* $i\,i$ is a *mica*

chimney, up which the hot air and gases pass, and thence through the *flues* j, j. $D\,D$ is the spider that, with the ring C,



(*a*)

FIG. 10.

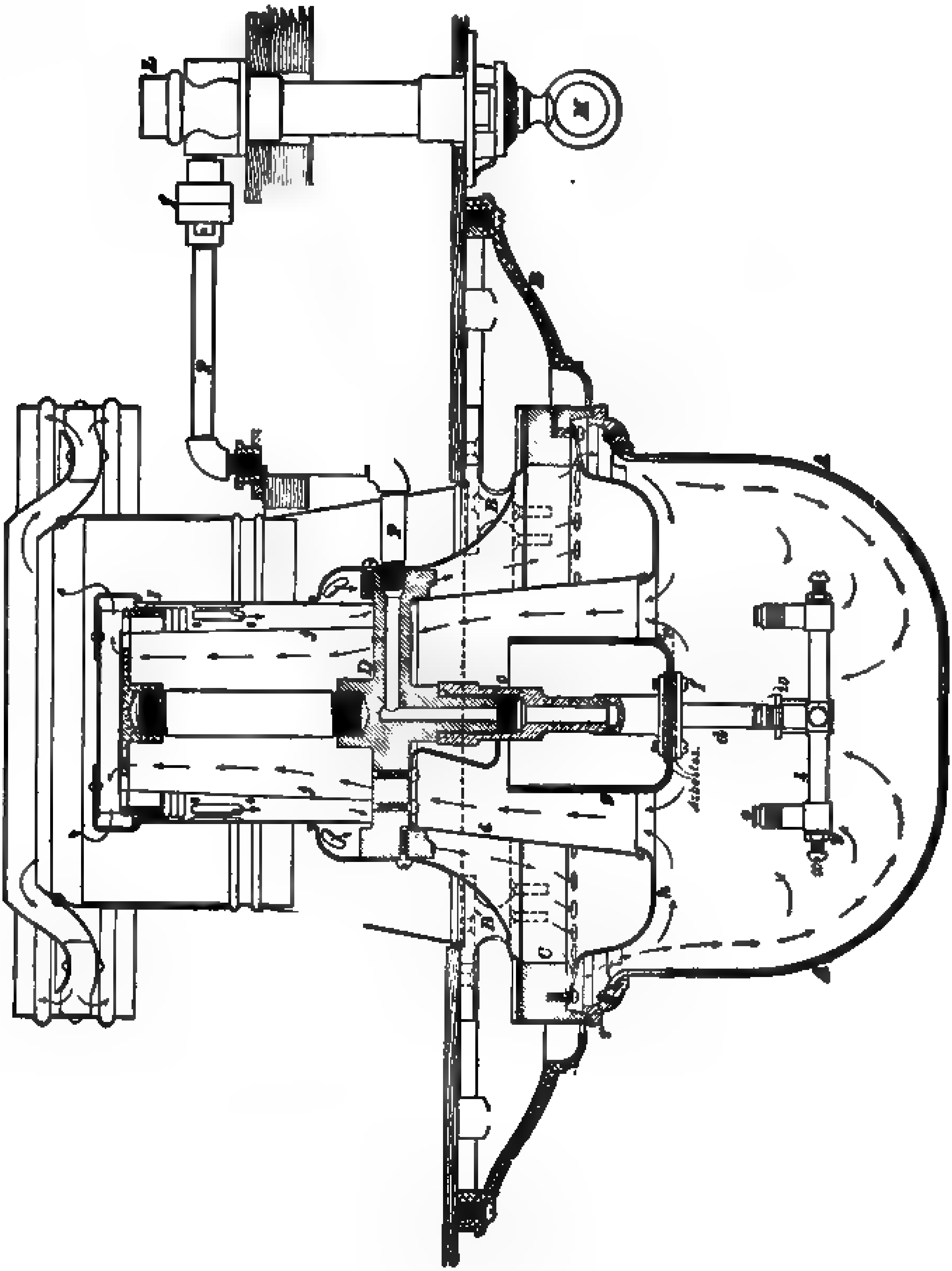
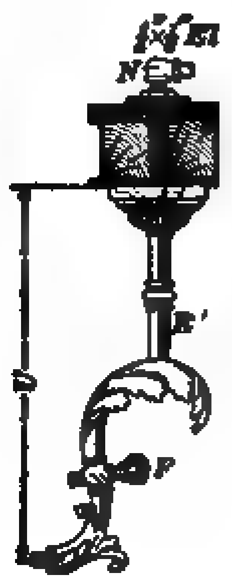


Fig. 11.

forms the framework of the lamp, the hinge being at k. At (a) are shown two views of the spring catch for locking the glass bowl A to the iron ring C; t is the catch, s is its spring, C is part of the iron ring, and r is the bezel or ring for the bowl. Two important dimensions have been noted on the illustration, namely, the distance between the bottom of ring reflector and the top of cluster where the burner screws in; also, the distance between reflector and top of burner when in position. Another important dimension is the distance between faces of ring and cup reflectors; it should be $\frac{1}{4}$ inch, as shown in the lamp next described.

13. Fig. 11 illustrates a type of lamp used on various cars. This lamp, as seen in position in the car, presents a very neat and elegant appearance. It is supported from the roof by means of the brackets B'. R is an ornamental ring running



(b)

(a)

Fig. 12.

round the lamp. The various other parts are lettered to correspond with those in Fig. 10. The descending arrows show the course taken by the incoming air, while the ascending arrows show the path of the escaping hot air and gases after leaving the flame and bowl. The glass bowl is made air-tight on the

rim by means of an asbestos wick, the same as in the case of the lamp shown in Fig. 10.

14.
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FIG. 13.

Pintsch gas and also electricity, there being two electric lamps provided, in case the latter light is desired.

In (*a*) is shown a sectional view of the lamp as made

transversely to the car. (*b*) is a view at right angles to the first, showing the gas arm *E'*. This arm is not seen in view (*a*), it being in the front part of the lamp, and therefore removed in order to show the latter in section. In the illustrations, *A* is the glass bowl and *B* the glass dome, both of which are electro-etched with elaborate designs. *C* is the cast-iron body ring, and *c* is an ornamental ring. *D* is the ventilating bell. *E* and *E'* are the lamp arms, the three marked *E* being plain arms, and *E'* the gas-way arm—the lamp cock in this latter arm being marked *F*. *G* is the extension arm carrying the electric lamp *L*, *H* being the socket by which the light is switched on or off. *I* is the socket cover, and *J* the lamp shade; *K* is the crown of the lamp; *M* is the ceiling plate; *N* is an ell piece connecting the roof gas pipe with the gas tube leading to the lamp. *T* is the ceiling thimble, covered with asbestos; *r* and *r'* are special rubber and iron washers, respectively; *S* is the arm spider, and *W* the electric wires.

The general design of the lamp body and parts is similar to that of the lamp shown in Fig. 10.

15. Fig. 13 is an illustration of an **Argand bracket lamp,** part of the bowl *A* being shown broken away, so as to disclose the chimney, burner, etc. in the interior of the lamp. *F* is the thumbscrew by which gas is turned on to the lamp; *d* is the gas tube conveying the gas to the burner *e*; *g* is the chimney; *r* is the globe ring or bezel; *a* is the asbestos wick to make the bowl fit air-tight against the ring *r*; *r'* is the globe-retaining ring.

ACTION OF THE LAMPS.

16. The special features of the lamps just described are the closed globe *A*, the *white porcelain* reflectors *g* and *h* (placed in the upper part of the globe above the flames, with an annular opening between them), and the peculiar manner in which the air supply to the flame is carried on.

All center lamps (various forms of which are shown in Figs. 10, 11, and 12) are so arranged that the incoming air is heated considerably before coming in contact with the flame,

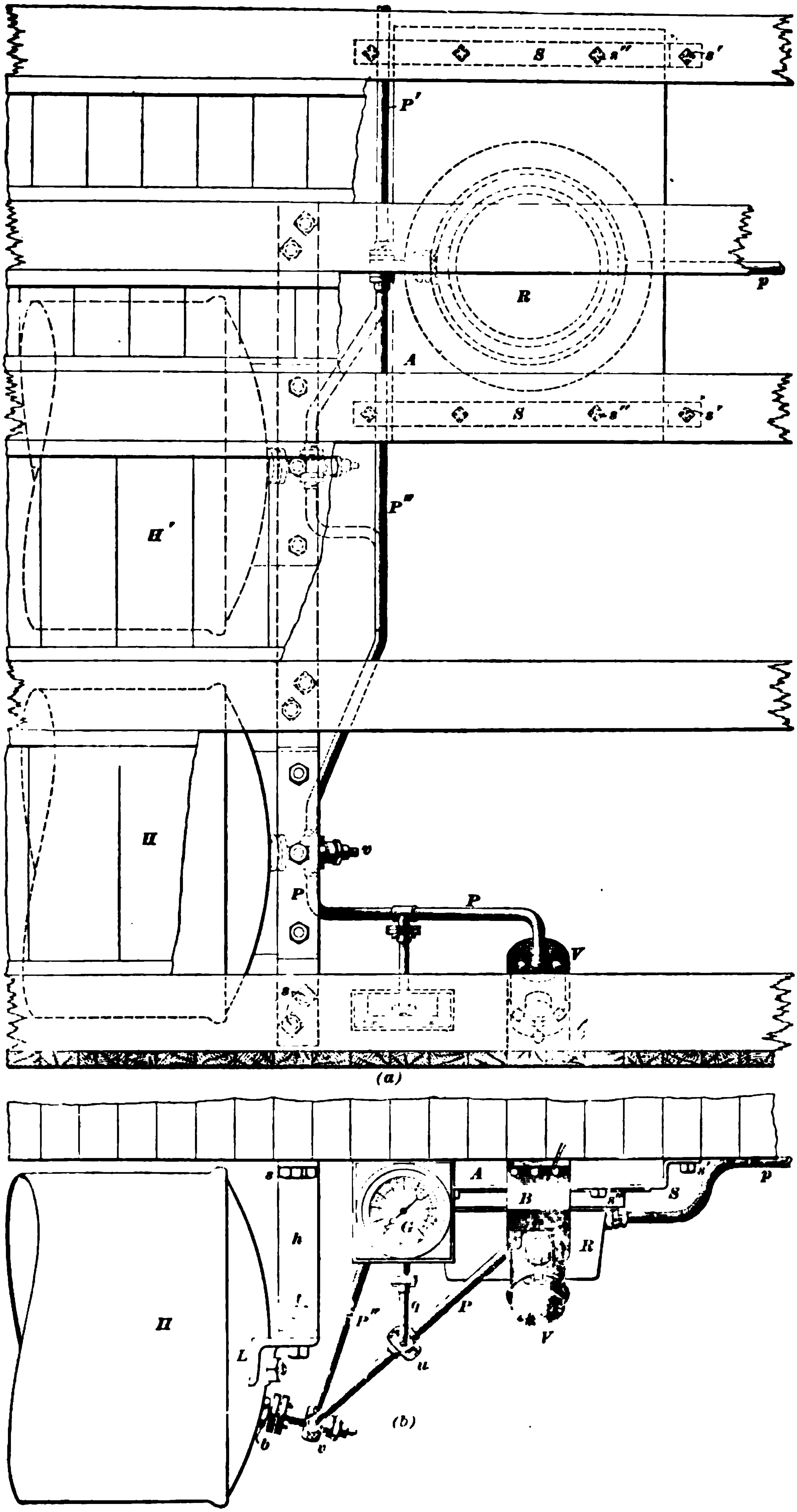


FIG. 14.

the result being increased whiteness and steadiness of light. It will also be noticed in all the lamps here shown, that the design is such as to reflect some of the light upwards through the mica chimney *i* and dome *B*, and so illuminate the roof of the car. As seen in Fig. 10, air is admitted through openings in the chimney *I*; passing downwards, it comes in contact with the side of flue *j* and so becomes heated. It then passes into the space between the dome *B* and the mica chimney *i*, where it is heated still more, the diaphragm *P* deflecting the air toward the chimney *i*, so as to be well heated. It passes from the space between *i* and *h* out of the holes in the outer edge of *h* and so into the bowl *A*. The tortuous course the air thus takes serves to protect the flame from any drafts the lamp may encounter. The gases of combustion thrown off by the flames pass through the space between *g* and *i*, up through the flue *j*, and out of the crown. The arrows in Fig. 11 show clearly the path pursued by the incoming and outgoing air.

In the lamp shown in Fig. 26, the gases pass out through the flues *Q* and *S*. In the vestibule lamps, shown in Fig. 27, the air is admitted through the inlets *v*, *v* in the ventilating chimney, passing thence downwards inside the space *O O* and then out through the holes in the body casting *z z* and so on down to the flames. The gases of combustion pass up through the flue *j*, past the sheet-iron deflecting plate *D*, on into the inner chimney *I*, and so to the outer air. Any air that may come in, more than is required for combustion of the gas, passes off into chimney *I*, through the space *a* between it and the flue *j*.

APPLICATION OF EQUIPMENT.

HOLDERS.

17. Arrangement.—Cars are fitted with one, two, or sometimes three holders, as circumstances demand. Fig. 14 and Fig. 15 (*a*) show the arrangement of a single holder, as adopted in Fig. 1. In Fig. 14, (*a*) is a plan view and (*b*) a side view; Fig. 15 (*a*) is an end view. When a second holder is used

Fig. 15.

on one side of the car, it is arranged as shown in coarse dotted lines in Fig. 14 (a), and marked H'. Its position, as seen from the end of the car, is shown in Fig. 15 (b), where it is also marked H'. When two holders are used, one at each side of the car, they are arranged as shown in full lines in Fig. 15 (b); or three may be used, as there shown.

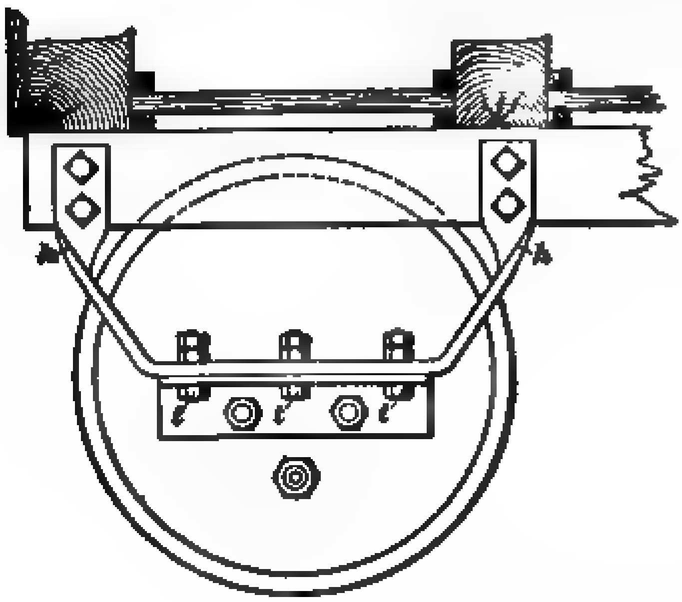


FIG. 16.

18. Method of Attachment. — Referring to Fig. 14, H is the holder, carried from the car framing by the hanger h, which bolts on to the car sills by lag screws s, and to the angle iron on the holder by bolts t. The holders should be hung so as to be about 1 inch clear of the car floor, and set in from the side of the car as much as possible. The end on which the inlet connection is fixed should be turned away from the nearest truck of the car, and the horizontal leg of the angle iron should be uppermost, in position for bolting to the hanger.

19. Hangers.—When the hangers are attached to the sills, they are simply *bent* as in Figs. 14 and 15. If, however, they

are connected to the cross timbers, they must have a *quarter twist* put in them, in addition to being bent (see *h*, Fig. 16). Put the bolts *t* in from below, and jam securely with the lock-nuts provided.

HOLDER VALVES.

20. The holder valve, Fig. 17, is connected to the holder in the following manner: The flange *f* is first screwed on to the inlet bushing *b* until the bushing projects through the flange about $\frac{1}{16}$ inch, as shown. Next screw the flange *f'* on to the end of the holder valve until there is about a $\frac{1}{16}$-inch projection there also. Then put a gasket in, as at *g*, and screw the two flanges up together by means of the screws *s*, *s*.

REGULATOR.

21. Regulator Board. The regulator is attached to the car by means of the regulator board, shown in Fig. 18. The regulator is secured to the board by $1\frac{1}{2}$-inch wood screws, a recess $\frac{3}{8}$ inch deep being cut in one face of the board for the regulator to fit into. Some *glazier's putty* is put into the edge of the above-mentioned recess before screwing up the regulator. The latter is so placed that its inlet and outlet

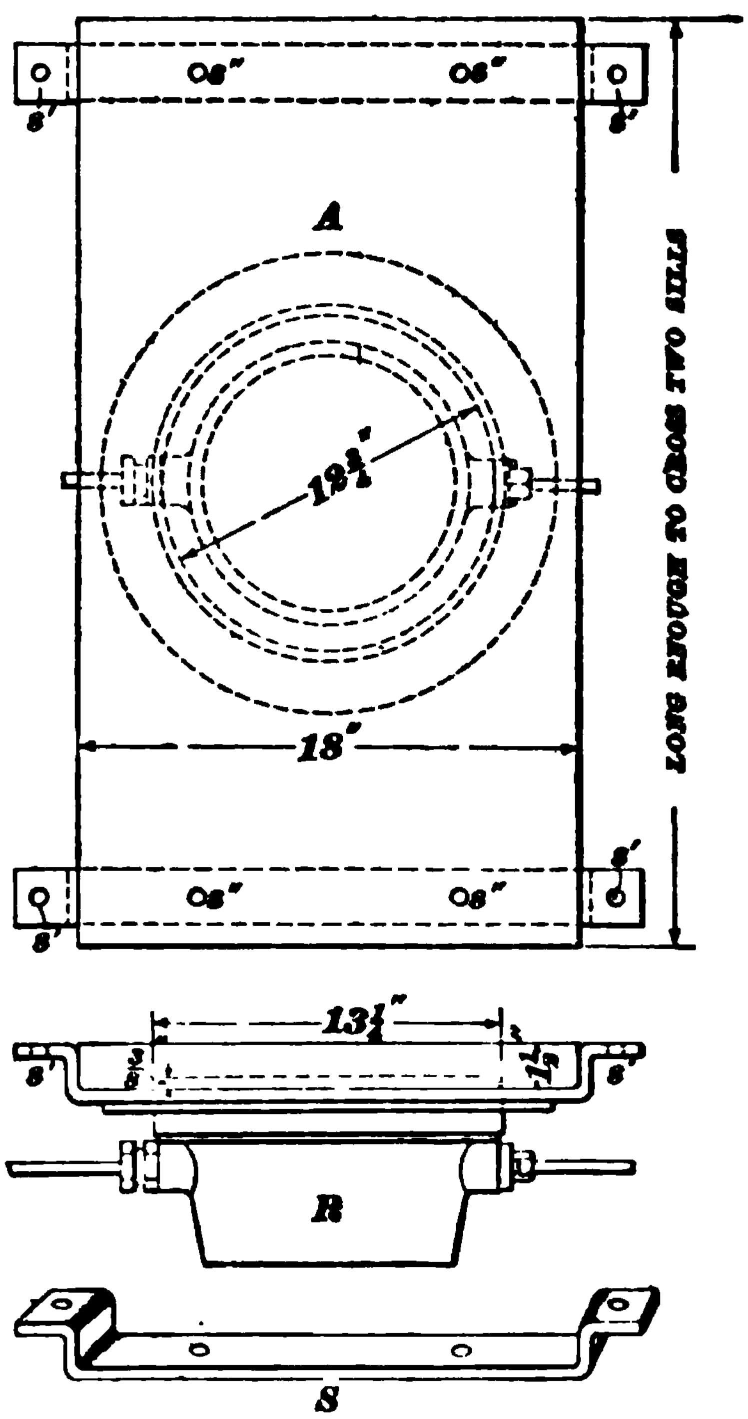


FIG. 18.

are *in line* with the short side of the board, as shown in the upper view. The board and regulator are then secured to the car frame by means of the straps and lagscrews shown in the figure, in which *R* is the regulator and *A* the regulator

board. The four end screws s' pass only through the strap, the four inner ones s'' passing through both the strap and board. The strap S is also shown separate in lower part of figure.

22. Connections.—The regulator fittings shown in Fig. 6 may now be connected to the regulator; they form the connection between the regulator and the high-pressure piping. Screw the flange f on to the flange tee F; then take off the temporary tin cover from the inlet connection of the regulator and make the connection with the regulator inlet bushing by means of the flanges f, Fig. 6, and f', Fig. 5, and the three screws provided. There is a *loose bushing* in the center of the flange f', as seen in Fig. 5 (a). Be careful to see that this bushing is properly in place; its duty is to hold the strainer of the inlet bushing in position, as well as to make the joint gas-tight. In the regulators now being sent out, however, this loose bushing is done away with, there being altogether fewer parts in making the connection between the piping and regulator, and any leak that may occur will be inside the regulator, so no gas is lost.

FIG. 19.

FILLING-VALVE BRACKET.

23. The **brackets** B that carry the filling valves are fastened to the side sills with three $2\frac{1}{2}'' \times \frac{1}{2}''$ lagscrews, as shown in Fig. 19 (see also Figs. 1 and 14). At (a) is shown one of the brackets separately.

When locating these brackets, care should be taken to set them far enough back to insure that the filling valve does not project outside of the car body. It will, as a rule, be found convenient to put this bracket between the end of the holder and the adjacent needle-beam or cross-tie timber. Having located and bored the holes, next secure the bracket in place temporarily with a couple of screws, and then insert the connection piece C.

GAUGE BOX.

24. The next step is to make a box for the gauge; this **gauge box** should be provided with a glass face, so that the reading can be taken. This done, screw the box, with gauge in it, to the under side of car, as shown in Fig. 14.

HIGH-PRESSURE PIPING.

25. Preparing the Pipes.—All is now in readiness for fitting the pipes up in place. All bends are to be made cold; no elbows or tees to be used. All pipes carrying the compressed gas (P, P', and P'') are to be $\frac{1}{4}$ inch, *extra strong*, with the exception of the gauge pipe q, which is to be $\frac{1}{8}$ inch, *extra strong*. These constitute the **high-pressure piping.**

As far as practicable, all pipes should be set to drain to the holder valves v, Fig. 14. The gauge pipe must drain down to the union u, Fig. 14 (b). Having bent all the pipes to their proper positions, proceed to screw the flanges on, first tinning the threads. See that the flanges "face" properly before connecting up. When all the piping has been fitted up fairly in place, take it down again and solder around the flanges. The pipe P, Fig. 19, must be passed through the bracket B before

the connection *C* is soldered on. Remove all burrs from the ends of the pipes and blow out all scale and dirt from inside the pipes, first jarring the latter well, to loosen up the dirt, etc.

26. Fixing Up the Pipes.—The *finished* pipes may now be put up for good, lead gaskets being used in all the joints (both in the pipe joints and also in those between holder valve and holder inlet at *g*, Fig. 17), and also in between flanges *f* and *f′* of the *regulator connection*, Figs. 5 and 6. Next screw up the filling-valve bracket *B* to the side sills and also strap up all the pipes firmly. Before screwing the filling valve to its bracket, the cover *D*, Fig. 19, must be taken off. To do this, remove the screws *s*, open the cover at the end, and rap with a piece of wood on the end *A* of the valve; the cover will then come off without taking the valve apart. Put a lead washer in at *g* and then enter the end *d* of the valve into the connection piece *C* and bolt up with three 1¾″ × ½″ bolts. Put the two upper bolts *t* in from the back, and the lower one *t′* in from the front, as shown by the arrows. By doing this, one is able to replace the valve at any future time, when the bolts are in place.

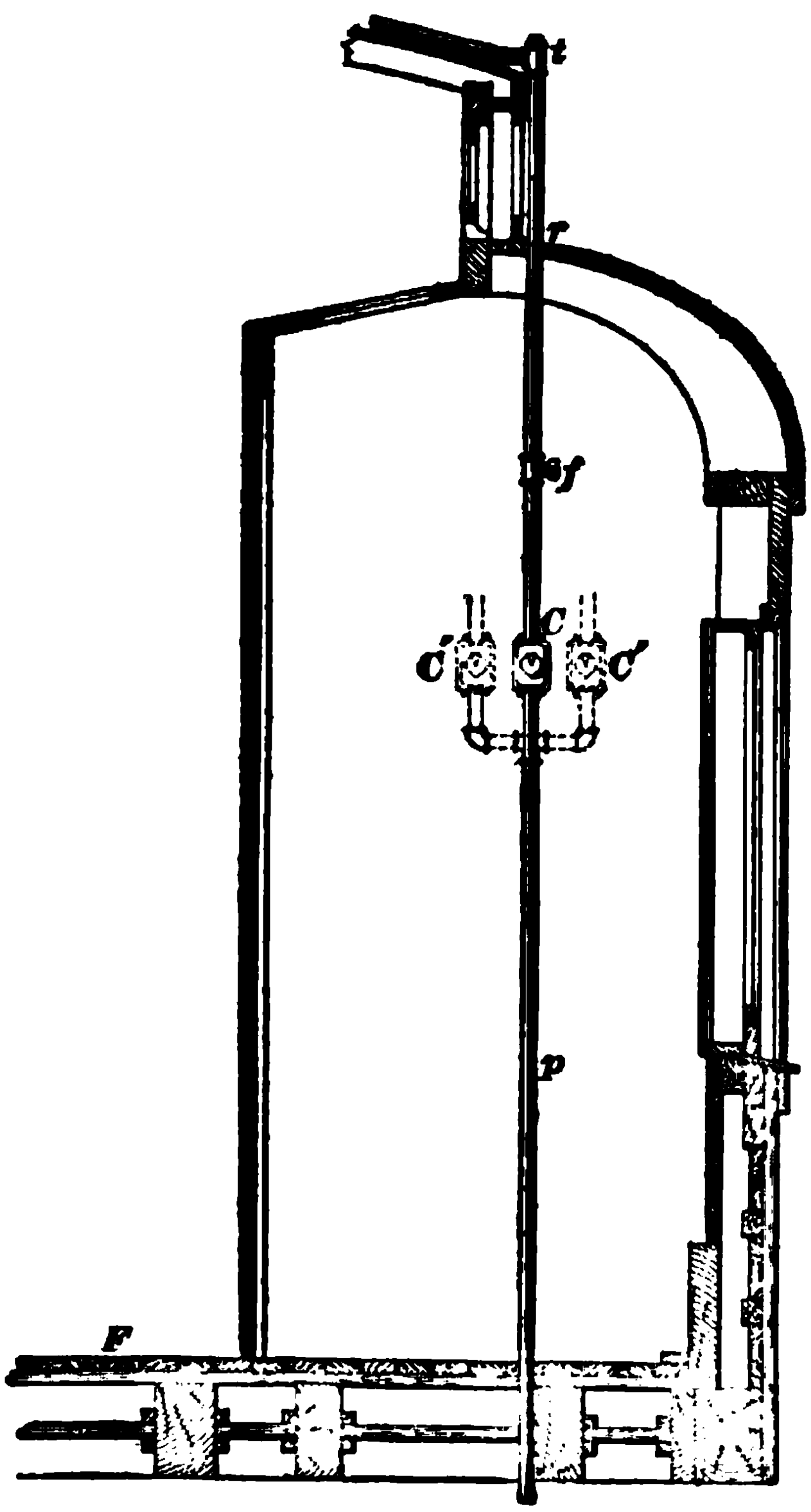


Fig. 20.

LOW-PRESSURE PIPING.

27. Preparing the Pipes.—The gas under low pressure is carried from the outlet of regulator up to the roof of the car by the ½ inch piping *p p*, shown in Fig. 1. The joints of this **low-pressure piping** need not be *soldered*, but merely made tight with *lead paint*. A tee and plug are used for making the upward turn at *t*. At a point *C* about 5 feet above the floor *F*, Fig. 20, is placed the main cock, closed in with the cover shown in Fig. 21. This cock should be so located that its *indicator* and the letter *A* are on the right-hand side, as shown in Fig. 9. At the point *r*, where the pipe passes through the roof, Fig. 20, the pipe should be tinned before putting up permanently, and then soldered to the tin roof when in place. The connection between the vertical pipe *p* and the cross-pipe leading to the main roof-pipe is made by means of the tee and plug shown at *t*.

FIG. 21.

As mentioned in Art. **11**, it is sometimes thought desirable to have two separate lines of piping on the roof, in which case there are two main cocks, arranged as shown dotted at *C'*, *C'*, replacing the single cock shown in full lines at *C*, Fig. 20.

28. Roof Piping.—Fig. 22 is a plan of the roof, showing the piping. As here seen, the pipe is carried along the roof about 18 inches from the center line. *Flange tees f* are placed in this pipe line wherever required for the lamps, and also for any bracket lights that are needed; angle flanges *a* lead down from the ⅛-inch pipe to the bracket and vestibule lamps. This piping should be laid on hardwood blocks about ¼ inch thick, spaced 4 feet apart, everything being secured in place by tinned-iron straps, shown in Fig. 23, using 1-inch wood screws, passing through both strap and wood into

the roof. A little thick paint should be put around each block so that no water may soak past the screw holes in the roof.

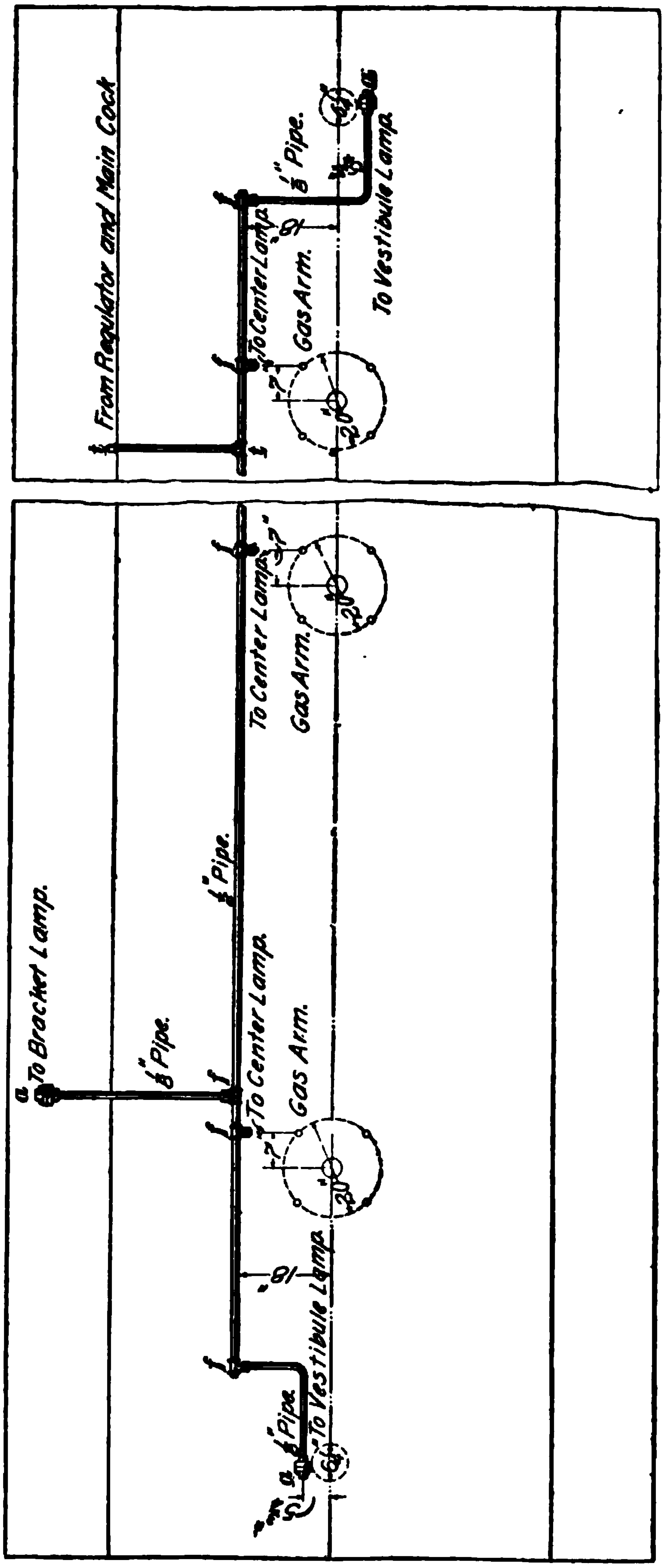


Fig. 22.

When vestibule lamps are used, it will be found advantageous to carry the roof pipe at the end of the car in the manner shown in Fig. 22, so as to facilitate making connections with the lamp cocks. The $\frac{1}{8}$-inch pipe leading from the main pipe down to the vestibule and side bracket lamps should be strapped to the roof and soldered to the tin where it passes through.

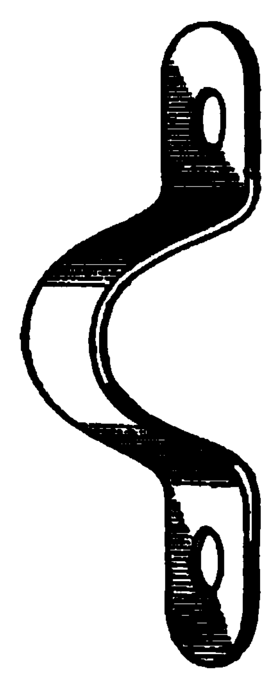


Fig. 23.

GASKETS.

29. The "lead" **gaskets** that we have several times mentioned are really in pairs, one lead and one rubber, the two always being used together; at least, they were so made until recently. The rubber gasket, or washer, is placed on the fitting first, the lead washer being put on next, with its collar inwards. Then, when the pressure comes on the joint in screwing up, the body of the lead washer protects the surface of the rubber one, its rib protecting the outer edge, and its collar the inner edge, of the rubber. The rubber is thus entirely enclosed within metal, and so protected from the action of the gas, which would injuriously affect it. The faces of the flanges of the various fittings are scored, the ridges thus formed making a tight joint in the lead. Nowadays, the Pintsch company are using solid lead washers of a flattened oval section, the metal being as near chemically pure as possible. These washers are found to give very good results.

ASSEMBLING THE LAMPS.

FOUR-ARM CENTER LAMPS.

30. A **four-arm lamp** is shown in Fig. 24, one of its three plain arms *E* being here shown, and also its gas arm *E'*, in which arm is the lamp cock *F*. The arm *E'* is screwed into the cast-iron ring at *a*, which opening connects with the gas-way tube *b*, as shown in Fig. 10. Wrenches should not be used for screwing these arms in; they can be put in by hand, grasping them close to the ball *G* on the lower end. Screw the pipe nipples *n* into the upper ends of the arms, as shown. Lead paint should be used on both ends of the gas arm, but it is not necessary for the plain arms.

31. Putting Lamp in Place.—Fig. 24 shows how the lamp should be put up. Place the rubber washer *r* over the top of the nipple and then the iron washer *r'* on top of *r*, and tighten up with the locknut *z*. A little putty should be put underneath the rubber washer before screwing the nut down.

Screw the ell *H* on to the top end of the nipple in gas arm *E'*. The pipe *p* leads from this ell to a tee flange *f*, shown in

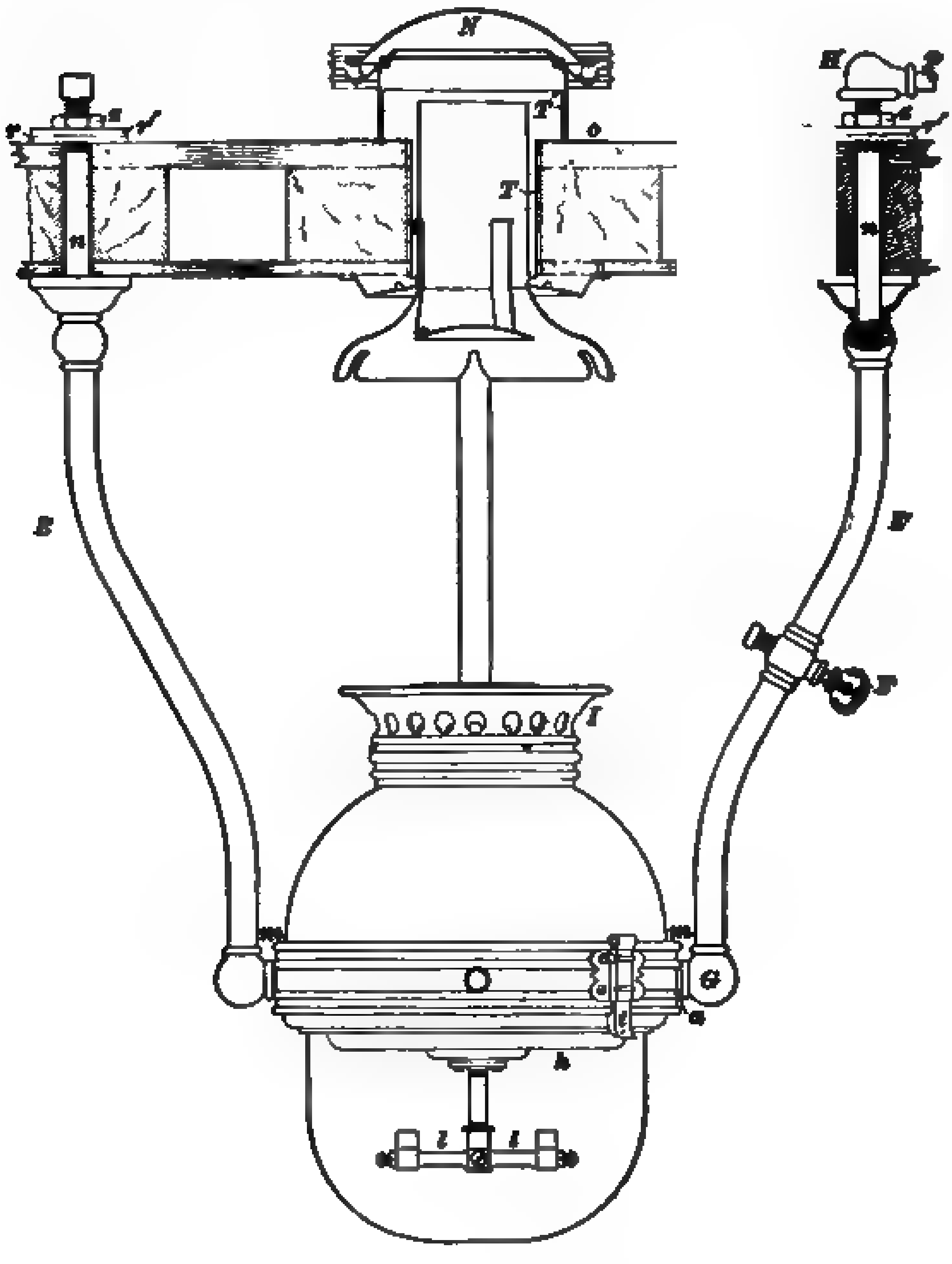


FIG. 24.

Fig. 22. *Caps*, as shown, are then screwed on to the ends of the nipples connecting with the three *blank arms*.

Be careful to see that all the gas ways in the lamp are perfectly gas-tight; they should all be tested by suction just before fastening the lamp up in postion. See also that all the

lamps are put up "square." The arms that carry the gas to the lamp should be on the same side of the car as the roof pipe is, and should all be towards that end of the car where the pipe passes up to the roof, Fig. 22.

It is best to make a templet for marking off the holes for the suspension arms and ventilating bell. The holes for the arms will, for lamps of ordinary spread, lie on the circumference of a 20-inch circle. The hole for the bell is central with this circle, and is made about $\frac{1}{8}$ inch larger than the tube of the

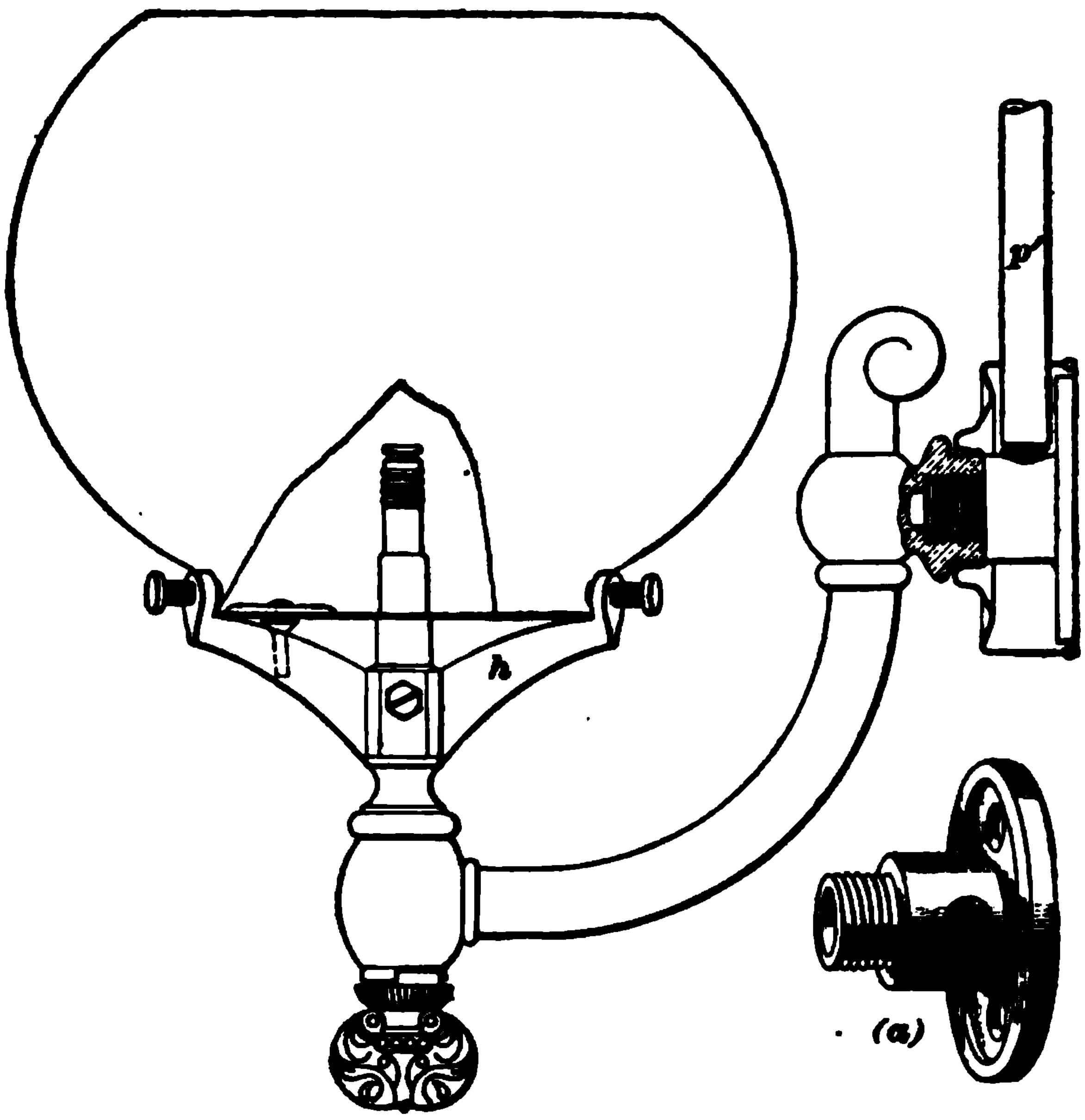


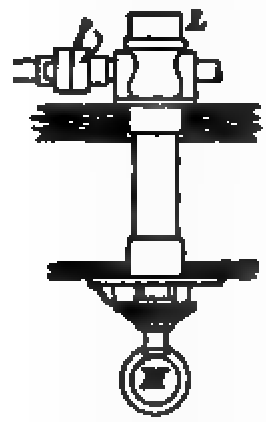
FIG. 25.

bell. A tin thimble TT' is next made and fitted to this hole, being made of such length as to reach down through the roof and extend about $1\frac{1}{4}$ inches above the roof. The upper end T' must be of such size as to let the ventilator N fit down over it snugly. A flange collar o secures the thimble to the roof, being soldered to each of them.

We may remark that the threads on the gas tubes, nipples, etc. of the various lamps shown are ordinary pipe threads; they are made coarse in the illustrations for the sake of clearness.

BRACKET LAMPS.

32. Bracket lamps are secured in position on the car by means of a fitting known as the *bracket-back*, the arrangement



g as shown in
25. This fitting
st of all screwed
to the $\frac{1}{8}$-inch
p' leading from
vertical pipe
feeds the roof
and is then se-
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unless some
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FIG. 26.

latter is provided.
The bracket-back is shown separately, to a larger scale, at (*a*).

CENTER SUSPENSION LAMPS.

33. Fig. 26 illustrates the manner in which a **centrally suspended lamp** is put up. First of all, the gas-way tube $b\,b\,b$ is cut off to the right length (according to thickness of roof) and is then threaded. The thimble T is put in from below. The tube b is locked in position by nuts q, q, above the roof casting J and below the lower frame casting K. Use glazier's putty between the roof casting and the roof timbers.

The dome B is put on by first removing the extension pillar c and locknut q', thus permitting the removal of the lower part of the lamp. The roof pipe p is connected to the gas tube by the ell H, the gas supply being controlled by the cock L, and the connections being made by the flange union f. At M is the thumb piece, with socket and plate, for working the cock L. We may here mention that no lamps of this particular style of construction have been made for some years past. Of course, there are great numbers of them in use, but the Pintsch company is constantly improving its apparatus, and discontinuing the output of parts that have been thus improved upon.

PLATFORM AND VESTIBULE LAMPS.

34. Fig. 27 shows the method of putting up the **platform lamps.** The lamp should be placed so as to bring the spring catch t nearest the door of the car; the cock $u\,u$ will then be on the right-hand side of the lamp to a person coming out of the car.

The *ventilating chimney* O should be cut to suit the thickness of the roof, maintaining the proper relation to the lamp body by working to the dimensions shown in the illustration.

The outer, or ventilating, chimney is to be soldered to the roof R, where it passes through the latter. Observe that the top of the ventilator M must be *in line* with the top of the ventilators belonging to the center lamps. Care must be exercised in keeping the *air inlets* v, v free; see that these spaces are not closed up with paint in the first instance and that they are kept clear afterwards. If the above two points relating to the ventilators and air inlets are not observed, the lamps will not burn properly.

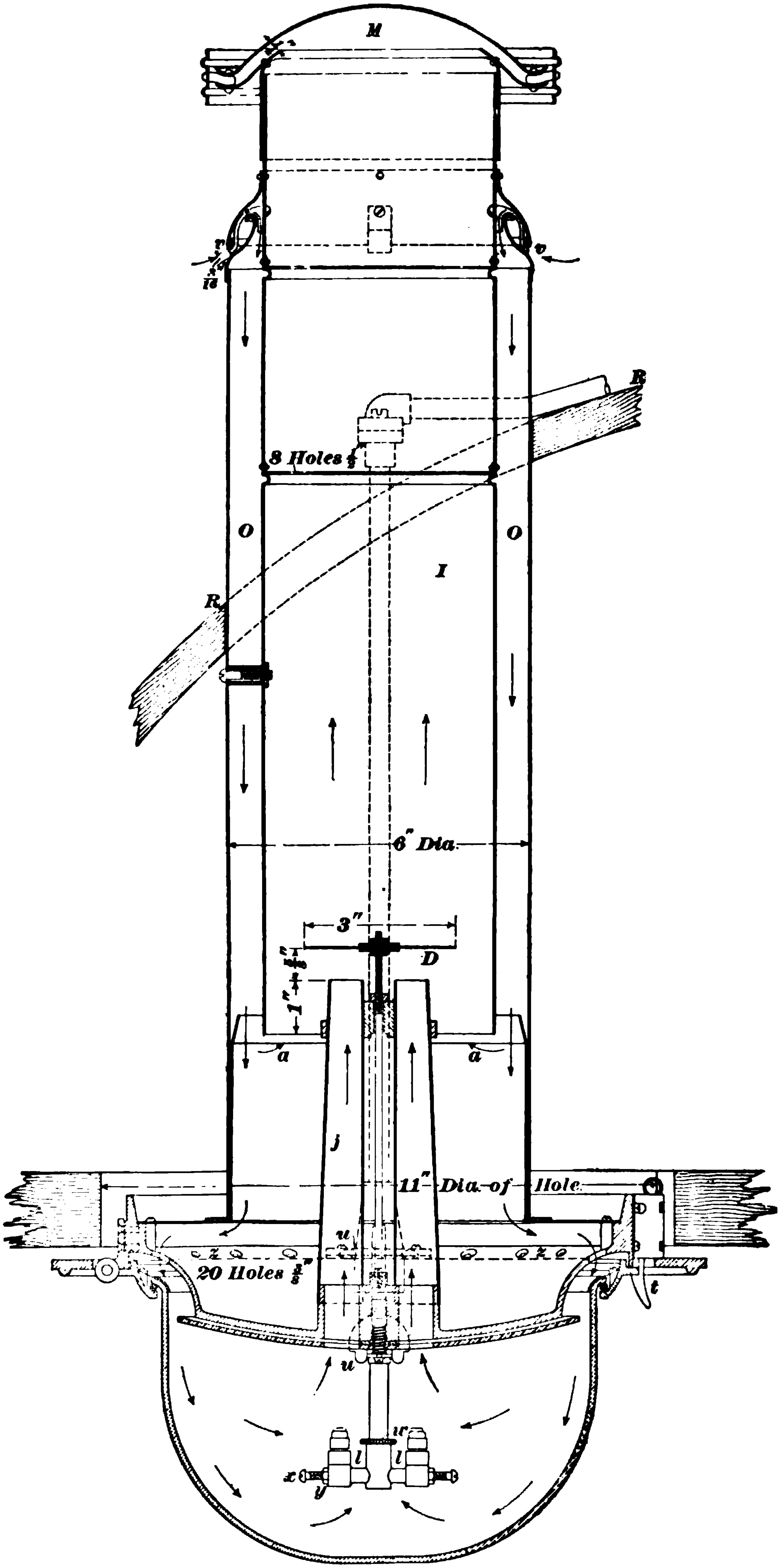


FIG. 27.

PUTTING ON THE GLOBES.

35. When about to put on the upper glass, or dome, of an arm lamp, first unscrew the *crown I* from the chimney of the lamp (see Fig. 24). After the dome is in place, put this crown on again, screwing it up snugly against the dome, so as to hold the latter on tightly.

Untwist a ring of *asbestos wick* and put it around the bottom edge of the dome at *m*, between the glass and the iron ring (see also Fig. 10). This makes the joint around the bottom of the dome air-tight.

There is no occasion to solder the ventilators to the roof, provided the thimbles are made to fit the ventilators closely.

BURNERS.

36. The **burner tips** to be used on all fixtures are No. 40, shown in Fig. 28. The threads of all burners should be painted with lead paint before screwing in. This burner consists of a small lava tip of the fish-tail variety, held in a special brass pillar. Such a burner consumes about $\frac{5}{8}$ cubic foot per hour. The No. 40 burner is recommended for all fixtures, but sometimes a No. 50 burner is used on the bracket lamps; one of these latter burners consumes about 1 cubic foot of gas per hour.

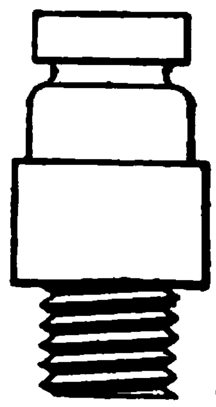


FIG. 28.

TESTING AND CHARGING.

TESTING THE EQUIPMENT.

37. When the car is fully equipped, shut off all the fixtures by closing their cocks. Also shut off the holder valves, ready for testing. To do this, remove cap *C* (Figs. 3 and 4) by means of key *K*, and then close the valve *v* by means of key *k*; these keys are shown in Fig. 3. Be sure and replace the cap *C* tightly.

Now connect a hose to *A*, Fig. 19, and then, by means of a force pump, or otherwise, put in a pressure of about 15 atmospheres (220 lb. per sq. in.). Then close the holder valve, and if the gauge shows that the pressure does not fall during an hour's time, the pipes, etc. may be passed. After testing, and releasing the pressure, the valves on the gas holders must be opened again. The above pressure test may be made conveniently with an air pump, such as is supplied by the Safety Car Heating and Lighting Co.

FILLING THE HOLDERS FOR THE FIRST TIME.

38. Assuming the gas to be available in the charging line, turn about 1 atmosphere of pressure into the holders and then

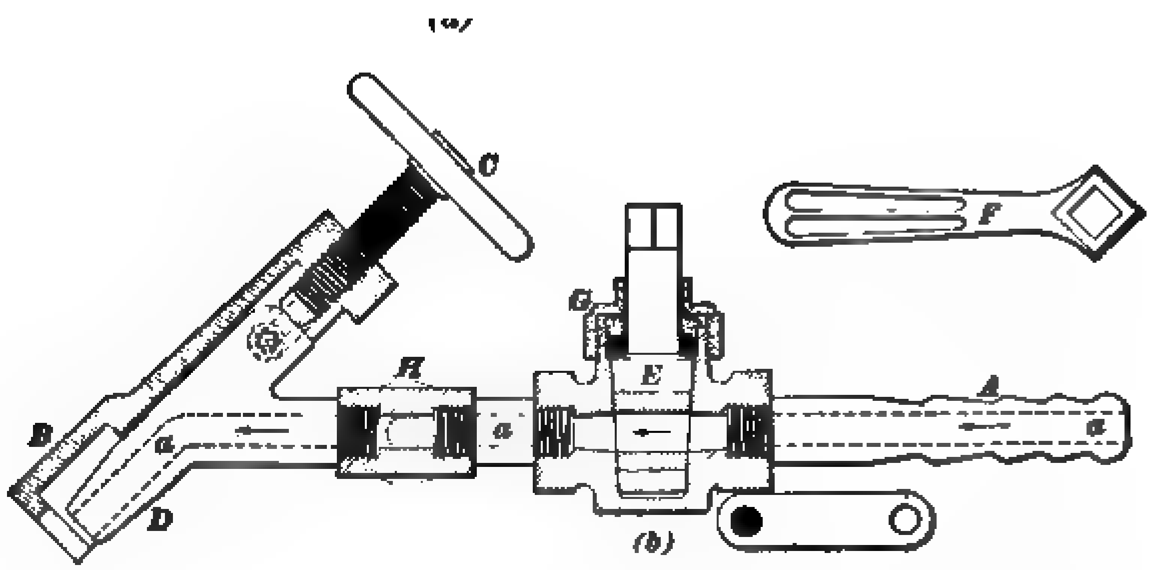


FIG. 29.

allow it to escape; fill them again with 1 atmosphere and once more allow the gas to escape. This is done with a view to

getting rid of the air in the holders, which it does to a large extent. Now fill the holders to 10 atmospheres and proceed to adjust the burners.

CHARGING THE CARS.

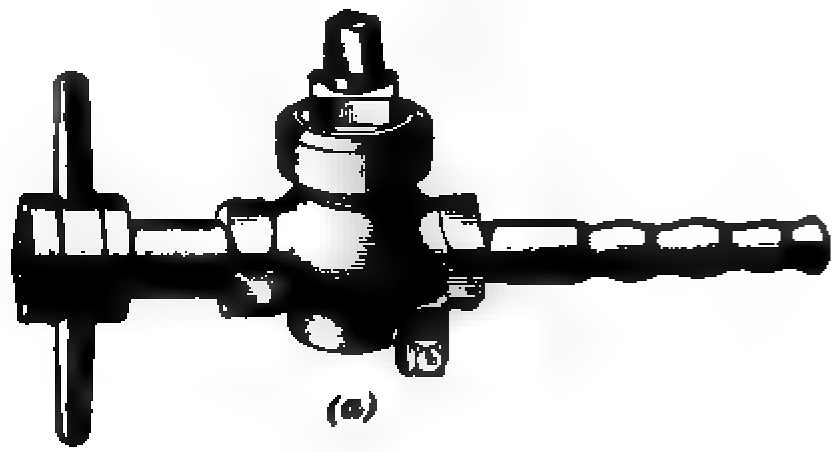
39. When about to charge a car the filling valve is connected to the hose leading from the charging line by means of a special *hose fitting* shown in Fig. 29, in which (*a*) is an outside view and (*b*) a sectional one. The charging hose is permanently secured to the nipple *A* of the fitting. In making the connection, the hose fitting is brought up against the filling valve so that the clamp *B* fits over the end of the valve and engages with the flange *n* (see Fig. 7). The hand wheel *C* is then screwed up, forcing the nozzle *D* into the end *A* of the valve, Fig. 19, making a practically tight joint, this being facilitated by the use of a small paper washer or ferrule that is slipped over the end of the nozzle before inserting the latter in *A*. The pipe-line valve being next opened, gas flows through *a a a* into the filling valve.

While passing from car to car during the operation of charging the train, the pipe-line valve need not be closed, the plug cock *E* being operated instead, using the wrench *F* for the purpose. This cock is kept in place by the cap *G*, a gland and packing being used, as shown. The connection for the pressure gauge is made at the tee piece *H*.

40. Another hose fitting in use is shown in Fig. 30, (*a*) being an outside view and (*b*) a sectional one. The hose is attached to the nipple *A*, and the hose fitting is connected with the filling valve by entering the nozzle *D* into the valve at *A* (see Fig. 19). The joint is made tight by screwing up the sleeve nut *I*; the thread *t* engages with the screwed end *T* of the valve. (This nut is shown in its two extreme positions in (*a*) and (*b*), respectively.) This fitting as here shown is provided with a plug cock *E*, the same as in the fitting just described, *G* being the gland cap as before.

We may here state that the hose fittings described in this and the preceding article are now supplied fitted with a *Jenkins*

valve instead of with a plug cock. The advantages of this valve are its easy operation and the reduced liability of leakage around the stem. Also, if at any time the valve should fail to shut off properly, it can readily be put in good condition by



(a)

FIG. 30.

merely changing a disk, whereas the plug cock in such a case would have to be ground in, and if the seat were very bad, the fitting might have to be removed from the hose in order to make use of a proper grinding machine.

ADJUSTING THE BURNERS.

41. Turn each burner so that its flame will stand squarely and in the right position, that is, so that the two small holes in the tip come in line with the cluster arms *l*, *l*, Fig. 10, etc. This cluster arm is secured in its proper position on the cluster stem by means of the locknut *w*. Adjust the screw *x* at base of burner tip, until, with all the other fixtures of the car lighted

and gas turned on full, the burner in question will be just on the point of "blowing"; then secure the check-screw by means of the locknut *y*.

The tops of the tips should be about $1\frac{9}{16}$ inches below the ring reflector *h* shown in Fig. 10, etc.

CLEANING OUT THE PIPING.

42. We have previously remarked the importance of blowing out the dirt from the inside of the pipes, jarring them at the same time to displace any loose scale. Sometimes, more especially if the above has not been attended to thoroughly, the jarring motion of the car will dislodge dirt and scale from the inside of the pipes, and the flow of gas carries the matter along and clogs the gas ways of the lamps. When such is the case, the scale, etc. may be removed by blowing out the piping in the following manner: Disconnect the pipe *p* at the outlet of the regulator (Fig. 1) and then stop up the outlet; open the main cock and also the cocks of all fixtures and take off all the globe holders (*h*, Fig. 25) from the brackets, and also the clusters from the lamps; next, by means of a hose, connect the pipe *p* (which has just been detached from the regulator) to one of the filling valves of the car, and then, by opening this valve, allow the gas from the holder underneath the car to blow through the pipes and lamps for a few seconds. This high-pressure gas will be effectual in cleaning out the pipes, etc. After this operation is completed, check all the burners again. While blowing out the pipes in the above manner all the car windows ought to be opened.

NOTE.—No *pressure* should ever be allowed on the regulator outlet, whether for the testing of pipes, for blowing them out, or for any other purpose.

CARE OF THE APPARATUS.

43. The apparatus of the Pintsch system is very simple, and, with ordinary care, will yield continuous good results. At the same time, however, it is an easy matter to bring about poor results through careless handling.

LIGHTING UP.

44. General Directions.—First of all, see if the main cock *C* (Fig. 1) is turned on full; if it is not, turn it on. Next open the globe of the lamp. Hold the light to the burner tips and turn on the gas so as to give a small flame—not so full as to reach the reflectors and smoke them. Then shut the globe and turn the gas up so as to give a flame of the size shown in Fig. 31.

45. Hints.—A careful and skilled attendant will, of course, look after each lamp individually, that is, he will drop the globe, turn on the gas, and then light up and close the globe. Now, very often one sees the attendant walk the whole length of the car (sometimes even of the train), dropping all the globes and turning on the gas at each lamp in turn; then he comes back again and lights them. All this time the gas has been escaping and filling the body of the lamp. By the time he gets back to the first ones, not only has there been quite a waste of gas, but also there is a violent "pop" on applying the light; even if this small explosion does no harm, it cannot do any good, to say nothing of momentarily alarming some of the passengers perhaps, and proclaiming to them the presence of an unskilled operator. *Each lamp should be lighted as soon as it is turned on.*

FIG. 31.

EXTINGUISHING THE LIGHTS.

46. To **extinguish the lights,** turn off the gas at each lamp; do not extinguish them by shutting off the supply at the main cock. Such a careless practice will assuredly lead to a bad waste of gas (to say nothing of its unpleasantness) owing to the main cock being subsequently turned on by some one who is unaware that (possibly) some of the lamps have been left on. After turning out all the lamps, close the main cock; then, if there are any leaks beyond that point, the waste through leakage will be inconsiderable.

POOR CHECKING.

47. Where there are check-screws, they should be adjusted so as to give the proper size of flame, Fig. 31. Lack of skill and care in adjusting the flames by means of the check-screws x (Fig. 10, etc.) leads to a loss of lighting power. It is a very easy matter to bring about a loss of 20 per cent. or more in lighting power due to **unskilful checking**. This item should therefore be carefully attended to.

UNSTEADY LIGHTS.

48. If a flame is not turned up so high as to "blow" and yet is seen to be **wavy** and **unsteady,** it is a sign that air is getting into the lamp where it ought not to. Generally the cause is either (1) that the mica chimney is broken, or (2) the joint between bowl and ring is not air-tight.

1. Carelessness in cleaning the chimney may have resulted in fracturing it, especially if it has been previously affected by too high flames. It should be borne in mind that these chimneys are necessarily somewhat frail, and should therefore be handled with a reasonable amount of care.

2. The joint between the glass bowl A and the ring r (Fig. 10) is made by means of an asbestos wick, the ring being held up against the bowl by a number of small screws. If all these screws are in place and the wick is satisfactory, the joint

will be efficient. If, however, through carelessness when assembling, only one or two of these screws are put back (and especially if they are not located evenly around the ring), the joint will not be perfect, and air will leak through. Or again, the catch *t* may be worn and the bowl allowed to drop away somewhat from the iron ring *C*, thus not making a tight joint.

CLUSTER STOPPED UP.

49. Sometimes the arms *l*, *l*, or the stem *d*, of the cluster may have become partially **choked.** When such is the case, the passage in the arm *l* may be cleared by running a wire through it, first taking out the check-screw *x*. If that does not prove sufficient, unscrew the cluster from the stem *d* and clear out the passage in the latter in the same way; or it may be necessary to use the twist drills furnished for the purpose. These drills are arranged to fit in a screwdriver handle, and, by their aid, any choked passages may readily be opened out.

DIRT IN BURNER TIPS.

50. It sometimes happens that dust or dirt from the inside surface of the pipes is carried away by the flow of gas and lodges in the burner tips, thus causing a badly shaped and smoky flame. This may be cured—but only for the time being—by tapping the cluster. The case should also be reported, so that the trouble may be permanently cured by taking off the cluster and removing the dirt; new tips may also be put in if thought desirable.

DIRTY LAMPS AND LOSS OF LIGHT.

51. Although the glass bowl (*A*, Fig. 10) is generally kept clean, yet the dome (*B*) is often neglected, perhaps because it is not quite so readily detected as the bowl. It is important, however, that this part also of the lamp should be attended to, as, otherwise, quite an appreciable amount of light will be prevented from reaching the upper part of the car, thus creating

a gloomy appearance, even if it does not affect the passenger much as regards ability to read, etc. The opalescent domes (those having a kind of lumpy surface) were formerly much used, but they are certainly unsatisfactory in so far as they catch and hold the dust, and also make it harder to dislodge when cleaning is attempted. Thus, they obstruct the passage of the light greatly, and, besides, we fancy that even when perfectly clean they would not pass as much light as a smooth-surface (opal) dome.

52. Smoked Mica.—By turning on the gas too full and thus allowing the flames to "blow," the mica chimney (*i*, Fig. 10) will become smoked, and the light that should penetrate it and pass out through the dome (*B*) is obstructed, thus throwing the car ceiling into gloom. Great care should be taken not to damage the mica during the process of cleaning it.

53. Smoked Reflectors.—The ring reflector (*h*, Fig. 10) and also the cup reflector (*g*) should be **kept clean.** If they are allowed to get smoked or dirty, the lighting power of the lamp will be greatly impaired.

54. Poor Reflectors.—We often come across reflectors that are considerably **burnt** and **chipped,** generally through the flames being turned up too high. It has been carefully determined by experimenting with such reflectors that from 8 per cent. to 10 per cent. of the light is lost. This is a serious matter, and should lead, in the first place, to careful operating of the system, and, secondly, to a prompt replacing of such damaged reflectors.

LEAKS.

55. It is particularly important that one should never attempt to locate **leaks** by means of a lighted match, taper, etc. Instead, soap suds should be employed. The smell of the escaping gas will locate the leak approximately; then, if soap suds are applied to the suspected pipes and fittings, the leaks will be evidenced by the formation of bubbles.

EQUIPMENT OF NEW STOCK.

GENERAL HINTS.

56. The number and character of fixtures required for the proper equipment of any car depends on (1) the class or kind of car; (2) the divisions of its space into staterooms, toilets, smoking rooms, passageways, etc.; (3) the spacing of the ceilings or head-linings; and (4) the amount of light required in the particular service for which the car is destined. In designing new cars there are certain points that have to be carefully considered; these will now be discussed.

LIGHTS REQUIRED FOR THE VARIOUS CARS.

57. **Private cars** are generally supplied with a four-flame center lamp in observation rooms and parlors, but when these rooms are more than 9 feet long, two lamps should be used. These may be supplemented by bracket lamps (either fixed or jointed, and having either single flames or Argand burners) placed wherever a concentrated light is deemed desirable. Staterooms may be provided with center lamps, having either four- or two-flame clusters, or else with bracket lamps. A bracket lamp should be placed near the toilet glass, in any case. Separate toilet rooms, pantries, and kitchens should be fitted with fixed bracket lamps, as should also the long passages at the sides of the car. Passages through the center of the car require two-flame center lamps, and open sleeping sections require four-flame center lamps. Vestibuled platforms require the regular two-flame vestibule lamp.

Sleeping and **parlor cars** should be provided with four-flame center lamps in the body of the car. In the sleeping cars, these lamps should be placed opposite each section; in parlor cars, they should be spaced about 6 to 8 feet apart. Smoking rooms, drawing rooms, etc. should have center lamps—four-flame as a rule. Large smoking rooms, however, should have five-flame lamps. Separate toilet rooms require, as a rule, fixed bracket lamps only, although jointed bracket lamps are convenient in ladies' toilets. The hallways just

inside the end doors can be satisfactorily lighted with two-flame center lamps; long passageways, with fixed brackets on end bulkhead, and vestibule platforms can be lighted with two-flame vestibule lamps.

Dining cars require four-flame center lamps opposite each table; two-flame center lamps in hallways, just inside the end doors; fixed brackets in the pantry, in the kitchen, in long passageways, and in the toilets; and vestibule lamps on platforms, whether the latter are vestibuled or not.

First-class passenger coaches require four-flame center lamps in the body of the car, usually four or five in number. They should be spaced not more than 9 feet apart, center to center. Where center lamps come close to end doors, and the toilet rooms have glass tops, the use of fixed brackets in these rooms can often be dispensed with. Vestibule lamps may be used over platforms, whether vestibuled or not.

Second-class coaches may be supplied with fewer center lamps, and five-flame clusters may be used if desired.

Combination cars should be treated as coaches, as regards the equipment at the passenger end, but the baggage compartment can usually be sufficiently well lighted by one four-flame lamp placed in between the side doors.

Baggage and express cars should be provided with one four-flame lamp to about every 15 feet of inside length of body. Adequate light is required near the side doors, and this should be borne in mind when locating the fixtures.

Postal cars require a large amount of light at the letter cases; slightly less will answer at the paper boxes and bag racks, and but comparatively little light at the storage end.

It is usual to "bunch" the center lamps near the letter cases, usually placing them out of the center line of the car, and as nearly as possible over the letter table. They should be spaced not more than 5 feet center to center, and may, in fact, be even closer. Four- or five-flame lamps should be used, according to spacing. Over the paper boxes, etc., the lamps should be spaced from 6 to 7 feet, center to center, using four-flame clusters. A single four-flame lamp will suffice for the storage end of the car.

REPLACING OIL LAMPS BY GAS.

58. In cars already built, the panels of the ceiling are usually such that it is found best to replace each oil lamp with a four-flame gas lamp. This, it is true, gives more light for each car, but that is a desirable feature, and, besides, more is expected of gas than of oil.

GAS CONSUMPTION.

59. Amount Consumed Per Hour.—Having settled on the fixtures required, the next thing is to estimate the total consumption of gas per hour, when all the lamps are burning "full on."

The accompanying table gives the consumption of gas for each kind of lamp.

From this table we can calculate the total amount of gas consumed by the fixtures of any car during one hour's full burning.

CONSUMPTION PER LAMP.

Description of Lamp.	Gas Consumed. Cu. Ft. per Hr.
Five-flame	3¼
Four-flame	2½
Two-flame	1½
Vestibule	1
One-flame bracket . .	¾
Argand	2½

60. Number of Hours of Full Burning.—In service, few, if any, cars (except postal cars) burn at "full" consumption throughout the entire number of hours of darkness during which they are in use. Bearing this in mind, and having determined the maximum hours of lighting, the amount of gas to be carried by any particular car for any given service may be easily computed. The calculated amount should then be increased by 15 to 20 per cent., to allow for delays, etc.

61. Number of Holders Required.—The necessary number and size of holders or tanks can be determined from the above-calculated results, with the aid of the table on the following page.

62. Pressure Measurement by Atmospheres.—In explanation of the annexed table, we may remark that 10 atmospheres is the **standard pressure** to which holders are filled, it is therefore here taken as a basis of calculation. The term *atmosphere* (sometimes written *atm.* for brevity) is used to indicate the pressure of gas in the holders. Each atmosphere, as indicated by the Pintsch gauges, represents a pressure of $14\frac{7}{10}$ pounds per square inch above that of the outside air.

If we take a vessel that is "empty" in the ordinary sense of the word, and that is open to the atmosphere, the pressure acting on the inside of it is, of course, that of the atmosphere, $14\frac{7}{10}$ pounds per square inch. The pressure acting on its outside is exactly the same, and, therefore, to all intents and purposes, the pressure within it may be regarded as 0. We set our gauge to register 0 when exposed to atmospheric pressure; so when fixed to such a vessel, the reading is 0. Now, if we seal the vessel up and exhaust the air out of it, it will not only be empty in the ordinary sense of the word, but it will also be devoid of air—will contain a vacuum, in fact. There will now be no pressure within it, as a vacuum gauge now applied to the vessel would denote, but there will still exist the outside pressure of $14\frac{7}{10}$ pounds per square inch.

CAPACITY OF HOLDERS.

Size of Holder.		Capacity in Cu. Ft. at 10 Atmospheres (About 147 Lb. per Sq. In.).
Length.	Diameter.	
9′ 6″	$20\frac{1}{2}$″	$212\frac{1}{2}$
8′ 6″	$20\frac{1}{2}$″	190
7′ 10″	$20\frac{1}{2}$″	175
6′ 1″	$20\frac{1}{2}$″	135
6′ 1″	$18\frac{1}{2}$″	110
6′ 1″	$16\frac{1}{2}$″	$85\frac{1}{2}$

Now, if we take two vessels of equal capacities, connect them together, then close them to the outer air and force all the air out of one into the other, a gauge on the latter will indicate 1 atmosphere of pressure. If the second vessel were twice as large as the first, and we forced all its air into the first one, the gauge would show 2 atmospheres—that is, its pressure

is increased 2 atmospheres over what it was at the start. The gauge registered 0 then, since the pressure inside the vessel was the same as that of the outer air.

If we had forced ten times as much air into the first vessel as it orginally contained, its pressure would then have been 10 atmospheres; so that, if the capacity of the vessel were 15 cubic feet, we should have to put in 15 cubic feet for every atmosphere we raised the pressure on the gauge. Therefore, if we multiply the number of feet in the volume of the vessel by the number of atmospheres on the gauge, we know how many feet of "free air"* we have put into the vessel over and above what was already in; and this represents the number of feet we can draw out at atmospheric pressure. Now, all this is true of gas as well as of air, so that if we had a holder of 15 cubic feet capacity, and its gauge showed a pressure of 9 atmospheres, we know that we have $15 \times 9 = 135$ cubic feet of gas, at atmospheric pressure, available for supplying cars. This is practically true, for the gas is supplied at but very little above atmospheric pressure, only 1 ounce per square inch, in fact.

EXAMPLE.—A car has 2 holders, each of 19 cubic feet capacity. The gauge shows a pressure of 9 atmospheres. What amount of gas is there available for supplying the lamps?

SOLUTION.— $19 \times 2 = 38$, and $38 \times 9 = 342$, the number of cubic feet the gas will occupy when released at atmospheric pressure. Ans.

If filled at a pressure of 10 atmospheres, there will be 380 cubic feet of gas for the lamps. When filled to 10 atmospheres, and containing, therefore, 380 cubic feet as just remarked, two such holders will supply 5 four-flame lamps, 2 vestibule lamps, and 2 bracket lamps, for about 24 hours' full burning, the consumption being 16 cubic feet per hour.

PRESSURE IN HOLDERS.

63. In determining the **number of holders** to put on a car, it is as well to bear in mind that an extra holder enables us to carry the same total quantity of gas with a lower pressure,

*By "free air" we mean air at atmospheric pressure. Thus, if we say there are 180 cubic feet of free air in a vessel, we mean that the air in the vessel originally occupied 180 cubic feet of space before being compressed—that is, when existing in the atmosphere. If we let the air escape into the outer air, it will expand and fill a space of 180 cubic feet.

thus entailing less liability of leakage. With only one holder, or, on certain cars, two holders, a pressure of 14 to 15 atmospheres is necessary. This is from 205 to 220 pounds per square inch, at which high pressure there must be more leakage than at the much lower pressure made available by using two and three holders, respectively.

LENGTH OF HOLDERS.

64. The construction of the car determines in some degree the **length of holder** that can be used. The appearance of the equipment is better if the holder is placed close to the sheathing or underfloor; therefore, the holder should not be so long as to necessitate its hanging entirely below the needle-beams or cross-ties.

The holders in most general use are either 9 feet 6 inches, or 8 feet 6 inches, long. Wherever possible, it is best to settle on one particular size of holder as standard for the road, and use that size exclusively, increasing the number of holders as may be required by the service of the car in question.

SPECIFICATION FOR LAMPS.

65. In ordering lamps, always give (1) the distance of the bell cord below the ceiling, (2) the total thickness and curvature of roof, and (3) the spread that the suspension arms should have. Unless otherwise ordered, lamps are made with suspending arms to meet the ceiling in a circle 20 inches in diameter, are given a total drop of 24 inches, and are finished in polished brass. Lamps with a drop of less than 20 inches require special ventilating bells and ventilators.

ORDERING MATERIAL.

66. In ordering material for the equipping of coaches or sleeping cars, one must specify (1) the size of holders and the number to each car, (2) the style and drop of lamps, and (3)

the number of lamps desired for each car. The Pintsch company can then make up a complete list of the fittings needed.

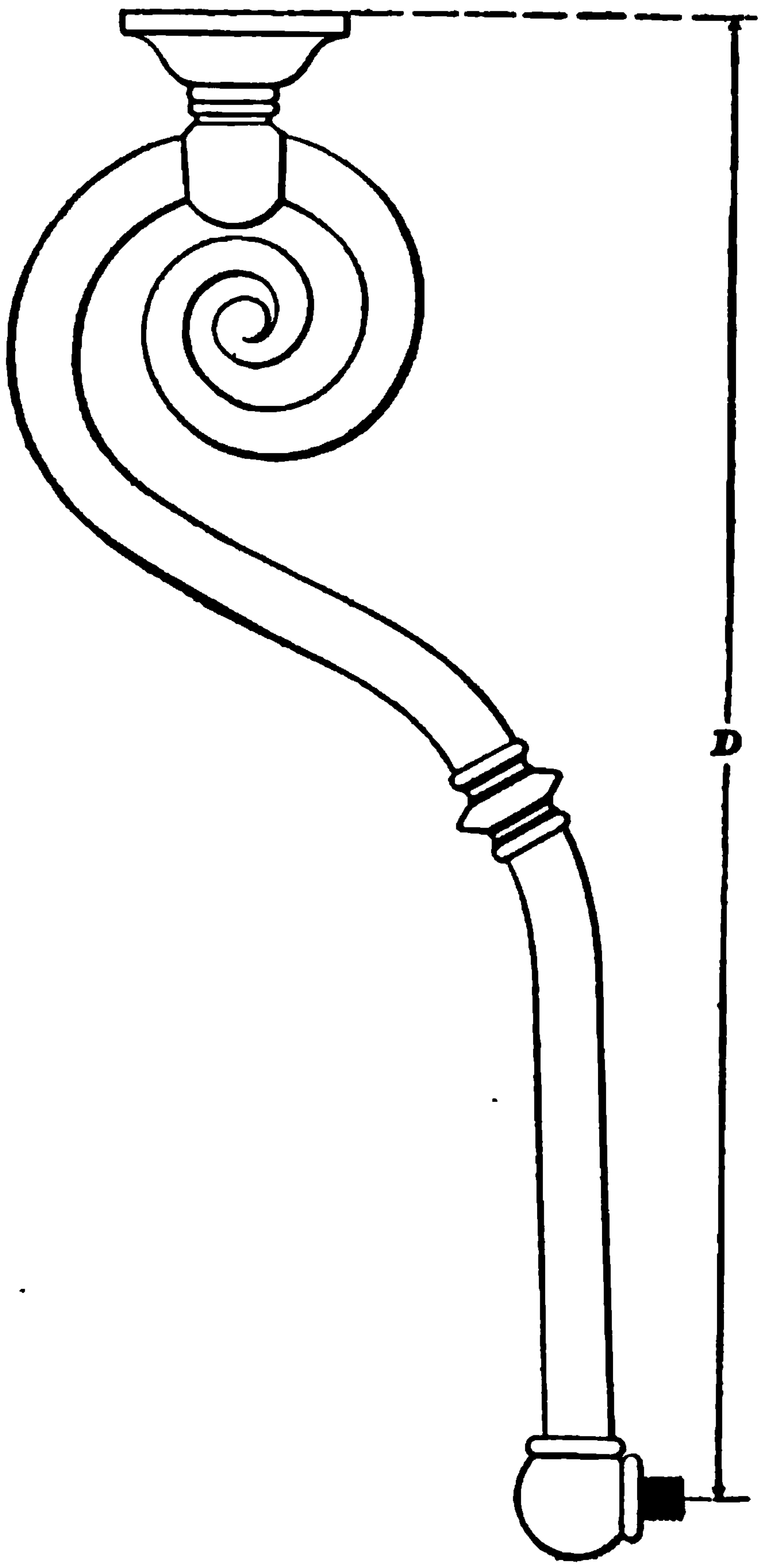


FIG. 32.

In ordering lamp arms for repairs, one must give the distance marked *D* in Fig. 32—the distance from center of arm nipple to top of ceiling cap. The catalogue number and the style of finish of the lamp must also be stated.

In ordering arms, ceiling plates, or arm spiders for the lamp shown in Fig. 12, care should be taken to specify whether or not they are gas-way arms, whether they are to have the electric fixtures, and also whether they are to be put in the center line of the car or at right angles to it. Also give the distance *U*, the length of the arm, measuring from center of nipple to the top of ceiling plate at the highest point. State further whether polished brass or bronze finish is desired.

COST OF SYSTEM.

67. The cost of lighting trains on the Pintsch system may vary slightly on different roads, but the following may be taken as indicative of good results:

COST PER 100 MILES.

Description of Car.	Equipment of Car.	Cost in Cents.
First-class coach .	4 chandeliers and 2 closet bracket lamps	22
Partition coach .	1 chandelier and 2 closet bracket lamps	15
Baggage car . .	3 chandeliers	12
Postal car . . .	7 chandeliers	25

The cost of lighting one baggage car supplied with 3 four-flame lamps, during the month of December, is given in the following table, based on a burning time of 9 hours and 35 minutes a day:

Cost per car per hour	5.09 cents
Cost per lamp per hour	1.69 cents
Cost per car per day	48.80 cents
Cost per lamp per day	16.27 cents
Cost per car per 100 miles	14.14 cents
Cost per lamp per 100 miles	4.71 cents
Average cost per 100 miles of entire equipment during a period of 6 months . .	19.20 cents

In another case, where each car was equipped with 2 holders carrying a pressure of 14 atmospheres, there being 5 four-flame aisle lamps, 2 two-flame vestibule lamps, and 2 two-flame closet lamps, the average cost per car per day was 56 cents, there being a total of 28 lights. The average cost of equipping a car was $365.

ADVANTAGES OF THE SYSTEM.

68. The adoption of the Pintsch system in all parts of the world has increased steadily during the past 15 or 16 years, and is now in use on some 95,000 cars and 4,000 locomotives. More than 14,000 cars are equipped with this light in the United States and Canada alone.

It was stated on a previous page that the gas used in this system was made from distilled petroleum. This is a "fixed gas," that is, a permanent gas—one that remains in a gaseous

state even when highly compressed. When compressed for use in cars, it has an illuminating power six times as great as that of ordinary coal gas. This latter—city gas—loses nearly all its illuminating power by compression; whereas, Pintsch gas loses only about $\frac{1}{10}$ of its power. Its illuminating power, when compressed to 14 atmospheres, is about 10 candles per cubic foot of gas consumed; that is, a lamp burning at the rate of 3 cubic feet per hour would give an illumination equal to that given out by 30 (Sugg) candles of standard specification.

PROCESS OF MANUFACTURE OF THE GAS.

GENERATING THE GAS.

69. The oil is contained in an underground supply tank located outside the gas works proper. It is pumped up, as required, to a smaller supply tank, whence it flows by gravity to the retorts in which it is treated. These retorts are of fireclay (which stands the heat better and is cheaper than iron); they are heated by coke fires in a regenerative furnace. The gas liberated from the oil leaves the retorts through pipes leading into a hydraulic main located above the furnace. From there it goes to the condenser in the purifying room, at which stage a test is made of the quality of the gas. The gas passes through tubes inside the condenser, cold water circulating around these tubes. All moisture and tar are thus removed from the gas, passing off to the tar well.

The pressure inside retorts made of clay must not exceed a certain amount; therefore, when such are used, an exhauster has to be employed for the purpose of maintaining a constant pressure of 1 inch of water inside the retorts. From the condenser the exhauster passes the gas on to the washer or scrubber, where all products requiring mechanical removal are extracted. From the purifier the gas passes through a meter and thence to a gas holder outside the building. It is then ready for compression, and, at this stage, further tests are made of its quality.

COMPRESSING THE GAS.

70. Economy is secured by compressing in two stages. The theoretical limit of the pressure at the first stage is the square root* of the total pressure. In actual practice, when the pressure attained in the second stage is to be 14 atmospheres, the first stage of compression is from 3½ to 3¾ atmospheres. The compression and cooling from the second stage causes the deposit of hydrocarbons, which are collected in pots outside the building. After being compressed, the gas is stored in welded steel holders. When two-stage compression is adopted, one of these holders acts as a reservoir or receiver between the first and second compressors.

The gas is led to the charging stations through *extra strong* 2-inch pipe, under a pressure of about 14 atmospheres. Where the length of the mains warrants it, expansion bends are provided. In the plant of the Manhattan Railroad, New York, there are 11 miles of this piping, the expansion bends being ½ mile apart. Notwithstanding the length of this piping, the loss in pressure is less than 10 per cent.

EFFICIENCY OF APPARATUS.

71. The Pintsch company test all their high-pressure valves and fittings, before sending out, to a pressure of 200 pounds per square inch, and all low-pressure ones to a pressure of 7 pounds, there being, in each case, an ample margin. Ten per cent. of a batch of valves, etc. are tested (being immersed in water while under pressure, so that any leak shows at once), and if any are not up to requirements, the whole are rejected. All the pressure gauges are also tested before being sent out, the margin of error allowed being only ¼ atmosphere, as already stated in Art. **9**.

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*The square root of a number is that number which, multiplied by itself, produces the given number. Thus, 3 multiplied by 3 equals 9; therefore, 3 is called the square root of 9. Likewise, 3¾ multiplied by 3¾ equals 14, very approximately; 3¾, therefore, is the square root of 14.

EXTENT OF SYSTEM IN PRESENT USE.

72. The following table, compiled in July, 1898, shows the extent to which the Pintsch system was then in use:

Countries.	Cars.	Locomotives.	Gas Works.
Argentine . . .	984		10
Australia. . . .	1,000		3
Austria	3,111		10
Brazil.	967	31	1
Bulgaria	33		1
Canada	20		2
Chile	46		1
Denmark . . .	45		3
Egypt.	2		3
England	17,800		87
France	5,210		22
Germany. . . .	34,325	3,566	71
Holland	3,012	5	9
India	6,458		10
Italy	1,522		4
Russia	1,943	50	13
Servia.	154		
Sweden	379		4
Switzerland . . .	371	2	1
Turkey	103		
United States . .	13,405		48
Total	90,890	3,654	303

ELECTRIC LIGHTING.

PRELIMINARY REMARKS.

73. Electric lighting for railroad cars is not a new thing. The L. B. & S. C. R. R., England, was, we believe, the first to introduce it, as far back as 1879. In the method there adopted, a dynamo was placed in the guards' van (i. e., baggage car), and belted to one of the axles. The Midland Railroad about the same time adopted a similar method. The South Eastern Railroad also had the electric light on their trains at least 12 years ago; a peculiarity of their practice, by the way, was to switch the light off partially when running between stations, and put it on full whenever a station was reached, thus giving a light during the journey proper that was not much better than the old oil lamps.

Efforts are now being made to introduce electric car lighting more extensively into use in this country. The systems at present in most general use employ either storage batteries or dynamos, or else a combination of the two. The dynamo is either driven by an auxiliary steam engine or from one of the car axles; in the latter case, it is driven either by a belt or by friction gearing.

74. Electric car-lighting is, to a certain extent, on trial, so to speak, and, therefore, nothing very definite and satisfying can be said thereof at present, as can in the case of such an old-tried and well-established system as the Pintsch Gas. All we shall do here, for the present at least, will be to give a general description of the principal methods in use. There are individual cases, possibly, of private systems—worked out by individual railroads—giving good satisfaction, but the data are not readily obtainable. And, besides, trainmen are not expected to possess an intimate knowledge of the apparatus, this being within the province of the electrician, who looks after this part of the car's equipment. As, however, several students have expressed their desire to obtain a general knowledge of the

plant used in electric car lighting, we have been led to include, in the present section, a brief descriptive account of the more common methods now in use. It will be understood that a more detailed account could not have been entered into without assuming the student to have engaged in considerable preparatory electrical study.

STORAGE BATTERIES.

GENERAL DESCRIPTION.

75. In this system, as used by one of our important railroads, the cars are fitted with 24-volt lamps, requiring a set of 12 cells of batteries to operate them to their full rated candlepower. The idea of grouping the batteries in sets is found to answer well, as one or more sets can be used, according to the nature of the car's demands. In express cars, one set is sufficient, while Pullman sleepers require the three sets, as there are as many as 27 lamps to supply.

BATTERY CELLS.

76. The **battery cells** are arranged in *trays*, 6 being placed in each tray, 2 of these constituting a complete set. Such a set (12 cells of batteries coupled *in series*) is capable of operating all the 24-volt lamps in the cars up to their full candlepower. With the appliances provided, two men can charge all the batteries on a train of average length in a quarter of an hour. It has been demonstrated in ordinary working that these batteries will light the cars for three nights at one charging; that is, they can light a train in a thoroughly efficient manner for a journey of more than 2,000 miles. Of course, the vital part of this system is the batteries, for on the proper performance of these depends largely the economy of the system. The users of this system point out as advantages that the train dynamo has been done away with, together with all rheostats and other regulating devices, and also that every car is made independent of the others.

RESULTS OF SYSTEM.

77. The company using this system has a total of 74 cars, with an aggregate number of 1,071 lamps, and during a period of 10 months obtained the following results:

DURATION OF LIGHTING.	
Car-hours of actual lighting per 10 months	135,342
Car-hours of actual lighting per month	13,534
Car-hours of actual lighting per day	451
Hours each car is lighted per day	6
APPROXIMATE COST.	
Cost per car per 10 months	$310.43
Cost per car per month	31.04
Cost per car per day	1.035
Cost per car per hour	.172
Cost per lamp per 10 months	20.70
Cost per lamp per month	2.07
Cost per lamp per day	.069
Cost per lamp per hour	.011

AXLE LIGHTING SYSTEM.

GENERAL DESCRIPTION.

78. A system has lately been introduced into this country in which there is a *dynamo* connected to an axle of the car, *storage batteries* being employed in conjunction therewith. As long as the car is running, the dynamo is generating electricity, which is stored in these batteries to be used as required. Electric fans are also operated by this same current.

The apparatus employed in the above system is very similar to that used in stationary electrical plants, when the current is stored by secondary batteries. The essential parts of the system under consideration are (1) a generator for producing the current, (2) two batteries for receiving and storing the current, and (3) a switchboard for rectifying and distributing the current. The axle is not a regular source of power; its speed of rotation varies from nothing up to a very high speed, and

also its direction is liable to be reversed—for the car may run in an opposite direction. If the electric energy were taken from a dynamo so driven, the light would vary in intensity with the speed of dynamo, and would go out altogether when the train (and, therefore, the dynamo) stopped. Provision, therefore, is made to meet these contingencies, and enable the lights to burn steadily at all times.

When the car is at rest or only moving slowly, the storage batteries supply the lamps with current. When the car is traveling at sufficient speed, the dynamo generates current and keeps charging up the batteries, and so virtually runs the lamps. An automatic switchboard is provided by means of which the dynamo is (1) switched into service when its *voltage* (i. e., its intensity) has reached a sufficient amount, (2) switched out again when its voltage is too low, and (3) has its armature terminals reversed when it is driven in a reverse direction.

FIG. 33.

GENERATOR.

79. Description.—The **generator** is of the "enclosed" type, and is placed in such a position as to be easily inspected. It is dust-proof, a necessary item when it is considered how the generator is subject to the varying conditions of the track.

The generator is illustrated in Fig. 33, which shows the general arrangement of the apparatus on the car. *A* is the generator, carried by hangers *h* from angle bars *b*, *b*; *B* is the pulley fixed on the car axle, and driving the pulley *C*, which is on the shaft of the generator. Formerly, the driving was done by means of a *belt connection*, but now the driving pulley operates the driven one by *friction*, the pulley originally used on the end of the generator shaft being now replaced by a friction pulley made up as shown in Fig. 34, where *A* is the casting proper, carrying the fiber filler *B*. These fiber fillers can readily be replaced when worn by removing the cap *C* and nuts *D*. The fiber pulley, if we may so call it, is kept up against the axle pulley by means of the *tension rod D*, Fig. 33.

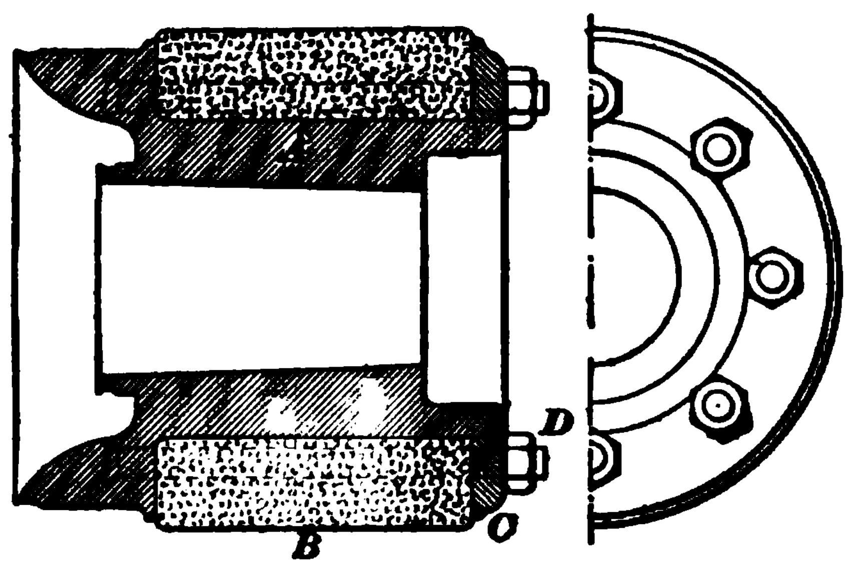


FIG. 34.

The dynamo should be oiled from time to time, and a general inspection made of the same. The bearings of the dynamo will run about 600 miles with one oiling.

80. Regulation of Generator.—The generator is made self-regulating, so that, however much the speed may vary, the batteries may not be charged at a rate exceeding the safe limit. The dynamo does not begin to generate the current until the train has attained a speed of from 10 to 12 miles an hour, at which speed the dynamo begins to generate, setting up its normal pressure of 45 volts. The electromotive force generated varies very little through a wide range in speed. The regulation of the machine is so good that it gives but very little higher electromotive force when the train is running 60 miles per hour than when it is running 10 or 15 miles per hour. This is accomplished by a combination of windings on the dynamo, by means of which the dynamo, instead of developing the usual increase of electromotive force when the armature

speed increases, weakens its field in such a manner as to cause the electromotive force to remain constant. The ordinary commercial dynamo would give an exceedingly variable electromotive force if driven from a car axle. There are three distinct windings or coils of wire on the field magnet of the generator: the *main shunt coil;* the *fine*, or *battery, shunt coil;* and the *series coil.*

STORAGE BATTERIES.

81. Duty.—Mention has already been made of the necessity for having some means of accumulation or storage of the electrical energy in such a case as the present, where the supply from the generator is so irregular—depending on the motion and speed of train. The capacity of the batteries is such that, under ordinary conditions, they are not more than about one-tenth exhausted before the dynamo starts up again, relieves them of their load, and recharges them.

82. Description.—The **storage batteries** consist of 16 cells connected up *in series*, having type E elements and Manchester positive plates. There are 9 of these plates for each element, 4 positive and 5 negative; they measure $7\frac{3}{4}$ in. × $7\frac{3}{4}$ in. The elements are housed in hard-rubber jars. Each car is furnished with two batteries of 16 cells each.

83. Capacity of Batteries.—An electric pressure of 30 volts has been decided on as the one most suitable and economical for lamps. The batteries when fully charged have a capacity sufficient to keep all the lamps burning for 20 consecutive hours. In case of accident, one-half of the lamps may be turned off and the remainder will keep lighted for about 37 consecutive hours. The slower the rate of discharge, the greater will be the efficiency of the secondary battery.

The batteries are contained in boxes bolted to the car floor. Instead of having a door in the box, through which to inspect the batteries, the box is lowered bodily for that purpose. The gain from housing them in this way is that the cell connections are not so easily disturbed.

The batteries should be inspected about every two months, when the electrolyte is tested and acid or water added.

On the bottom of the jars are ribs 1 inch high, to provide space for the accumulation of sediment, and to prevent short circuits from that cause.

84. Care of Batteries.—The three great evils to which a storage battery is, as a rule, subjected are (1) a too rapid discharge, (2) a too rapid charge, and (3) neglect.

1. *A Too Rapid Discharge.*—This takes place when the call for current is greater than the battery can supply—a condition, it is claimed, that can never occur with this system, because the number of lamps is never greater than the battery can safely carry.

2. *A Too Rapid Charge.*—In the present system, this contingency is guarded against in the design of the dynamo, the pressure in which can never rise above 40 volts, however fast it may be driven. At this pressure (40 volts) the batteries cannot receive their charge at too rapid a rate.

3. *Neglect.*—By "neglect," as used in this connection, we mean allowing the battery to stand for too long a period without charge or attention. It is a golden rule in connection with storage batteries that, to keep them in good condition, they must be continually used. As, in the present case, the battery is charged almost every time the car moves, this mode of neglect is pretty thoroughly obviated. The storage battery being thus continually charged and discharged, will last a very long period.

SWITCHBOX.

85. The output of the dynamo is brought up to the **switchbox,** which controls and distributes it. This switchbox, shown in Fig. 35, is a small lock-up box placed in the car, and intended to be opened only by the proper inspector at the terminal stations. It requires no attention from the trainmen, performing its duties automatically, as far as they are concerned.

It contains the switchboard, and also the ammeter that measures the amount of current being used. A is the ammeter, S the main-light switch, R the relay or make-and-break switch, and F, F the fuses.

86. Duty of Switchboard.—The **switchboard** has many important duties to perform, which it does automatically—or by hand, if occasion arises. Its chief duty is to rectify

Fig. 35.

the current as it comes from the dynamo, so that the batteries are always charged in the right direction, regardless of the direction of rotation of the armature.

87. Make-and-Break Switch.—A device of much importance is the **make-and-break switch** R, Fig. 35. When

the train gets into motion and the generator starts revolving, the electromotive force of the dynamo begins at once to increase; as soon as it is slightly higher than that of the battery, the main switch closes, and, in so doing, establishes the circuit between the dynamo and the battery, as a result of which the battery takes the current and is charged. Similarly, when the electromotive force of the dynamo drops to a level with, or below, that of the battery, which occurs when a train is slowing up for a stop, the switch also opens.

88. Dynamo Switch.—In addition to the automatic switch, the switchboard is provided with three hand switches and a dimmer. The most important of these switches is the one that establishes connection between the dynamo and batteries. If this switch is not closed, the dynamo cannot be connected and so supply current. The source of supply is then stopped and the batteries are no longer being charged. If, on the other hand, this switch remains closed all the time—whether car is running or at rest—the batteries are all the time exciting the field magnets of the generator through the shunt, thus wasting current and performing useless work. In practice, the custom is to cut out the dynamo if the car is laid up for repairs, or is withdrawn from service.

89. Battery Switch.—The second switch is operated by hand, and connects one battery with the light circuit, and the other with the dynamo, and vice versa. This switch is only operated when light is taken from the batteries. It remains stationary when the light is taken direct from the dynamo. It is so arranged as to put it out of the power of careless attendants to make a mistake.

90. Main-Light Switch.—The third switch is the **main-light switch** *S*, Fig. 35. This is also worked by hand, being turned on or off according as the light is or is not required.

The fourth hand switch is the **dimmer**, regarded somewhat as a novelty in railroad car lighting. Its purpose is to cut down the intensity of the light—varying it from full candlepower down to as low a degree as required. This is achieved by attaching a German silver resistance or a carbon rheostat to the

switchboard and sending the current through it when it is desired to dim the light. This resistance cuts down the pressure applied to the lamps and thus lowers their candlepower. This device is found convenient at night, when passengers desire to sleep. The output of the generator is registered by the ammeter *A*, which appliance is also useful inasmuch as it shows at once when anything about the machinery is out of order.

WIRING.

91. The **wiring** for the light circuit differs but slightly from ordinary house wiring. Provision is made in case of the dynamo failing, it being arranged that two cars may be connected and the disabled car run to the terminal, using the light from the batteries of one car only. Before making this connection, the light switch in the disabled car must be turned off and also one-half of the lamps in each of the two cars turned off. If this precaution is omitted, and all the lamps in the two cars continue to draw on the one battery, this battery will be discharged too rapidly and its protecting fuse *F* will burn out.

CAR HEATING.

INTRODUCTION.

1. The methods of heating railroad coaches have improved from time to time during the last 20 years until they are now at a point where the earlier methods seem crude by comparison.

The early method of heating was by stoves. These were not satisfactory, inasmuch as their heat was not readily disseminated throughout the car, being limited to their immediate neighborhood. Besides this, when wrecks occurred, the stoves generally set fire to the cars and so greatly aggravated the catastrophe.

At the present time, on all progressive roads, more efficient methods have been adopted—the most important one being that of heating by steam from the locomotive, using either live or exhaust steam. Naturally, the severe climatic conditions in this country led to considerable thought on the subject of car heating, with the result that we now have several very safe and efficient methods in general use, the most important ones of which we shall consider in detail.

THE BAKER SYSTEM.

GENERAL REMARKS.

2. The first scientific and successful attempt to grapple with the important question of car heating seems to have been undertaken by William C. Baker. True, the Baker heater is a stove containing fire, but the common objection to the fire stove—that it is liable to set the car on fire in case of a wreck—has been gradually minimized, the heater being now built so substantially and carefully as to practically insure safety from fire in the event of a wreck. Besides, steam from the engine is generally used to heat the water, fire being used in the heater

only in the event of the car being detached from the source of steam supply.

3. In Fig. 1 is shown the latest style of ordinary Baker heater, in which *A* is the generator coil, sometimes spoken of as the water coil; *B*, the fire-pot; *C*, the inside casing; *D*, the outside casing; *E*, the top casting; *F*, the safety plate; *G*, the base of the smoke flue; *H*, the feed-door; *I*, the ash-pit; *J*, the ash-pit casting; *K*, the base of stove and bottom of ash-pit; *L*, the grate shown in position for dumping; and *M*, the rocking bar and shaker for the grate. The castings *E* and *J* are perforated, as shown, so as to permit of an upward circulation of air through the space between the casings *C* and *D*. The air between the casings is heated, and so expands and consequently rises, while cool air is forced in through the holes in the casting *J* to take its place, thus maintaining an upward circulation of the air. The generator coil *A* is connected to the heating system and is always filled with the liquid used in the system; the heat from the fire heats the liquid in the coil *A*. The liquid expands, rises, and passes out of the coil at the top, while cooler liquid enters the coil at its lower end to take the place of the water heated; thus an upward circulation is maintained through the coil *A*.

FIG. 1.

CIRCULATING DRUM.

4. In addition to the fire enclosure and water coil, which make up the heater proper, the Baker comprises certain other apparatus, namely, a **circulating,** or **expansion, drum,** and the necessary radiating pipes, cocks, etc., through which the hot water is carried to all parts of the car.

This circulating drum, shown in Fig. 2, is always attached to the highest point of the heater—on the roof of the car for choice. Its purpose is to hold the water required for the circulation, after the pipes are all filled, and also a sufficient quantity as a reserve. The drum is placed horizontally, as in Fig. 3. The cock *C* is located so as to utilize the lower half of the drum for water storage. The upper half serves as an **air chamber,** which acts as an expansion chamber, and is indispensable in securing free circulation. The air that is freed from the pipes when the water is first heated, rises and gathers in this drum. The bottom of the drum has two tapped holes, *a* and *b*, into one of which enters the upflow pipe from the heater, while from the other runs the circulating, or downflow, pipe that carries the hot water through the car.

FIG. 2.

If the fire were allowed, through inattention, to run on unchecked, or the water circulation were impeded, the pressure in the heater might mount dangerously high. It is therefore essential that a pressure relief or safety valve be provided to release the pressure before it reaches the danger point. The latest appliance is a cast-iron **safety vent** *v*, Fig. 2, screwed into the top of the circulating

drum. This vent is a single casting without any joints; its top is thinned down to a certain specified thickness, thus providing a weak place which yields when the pressure attains a certain degree, and allows the top to be blown off.

When the top is thus blown out, a new safety vent is required, but the bushing may be used again. More or less water will be lost when the top blows off, which must be renewed. The fire must be put out as soon as the safety vent gives away, in order to protect the heater coil.

THE CAR PIPING.

5. Fig. 3 shows a method of piping a car for the Baker system of heating. The expansion drum D is placed horizontally on the roof, while the heater, represented here by the heater coil A, is placed as low down as practicable, namely, on the floor of the car. R is the hot-water **riser**, or upflow pipe, through which the heated water ascends into the drum D; P is the pipe through which it descends into the car again on its circuit through the latter. Near the floor of the car, pipe P joins with the line of piping p, which runs to the the far end X of the car, then turns and in a series of loops, under the seats, comes back to point a, where it crosses over to the other side, makes a turn at a' and runs through the pipe p' to the same end X as before; thence it returns in a series of loops, makes the return bend at end Y, recrosses the car at b, and at b' starts to return to the heater, entering the bottom of the coil at b''. The arrows serve to make clear the course of the circulation.

The pipe, in crossing the car, dips down below the floor at d, as shown, a **T** fitting being placed at t. At e is a drain cock to drain off the water when required. The car is represented as being broken in two, and the two parts brought close together.

CIRCULATING ACTION.

6. As the water in pipe R becomes heated, it expands and rises up into the expansion drum. The water in the pipe P is cooler than that in R, consequently, it weighs more, and thus exerts a pressure on the water in pipe p, causing it to circulate in the piping and reenter the coil A at its lower end.

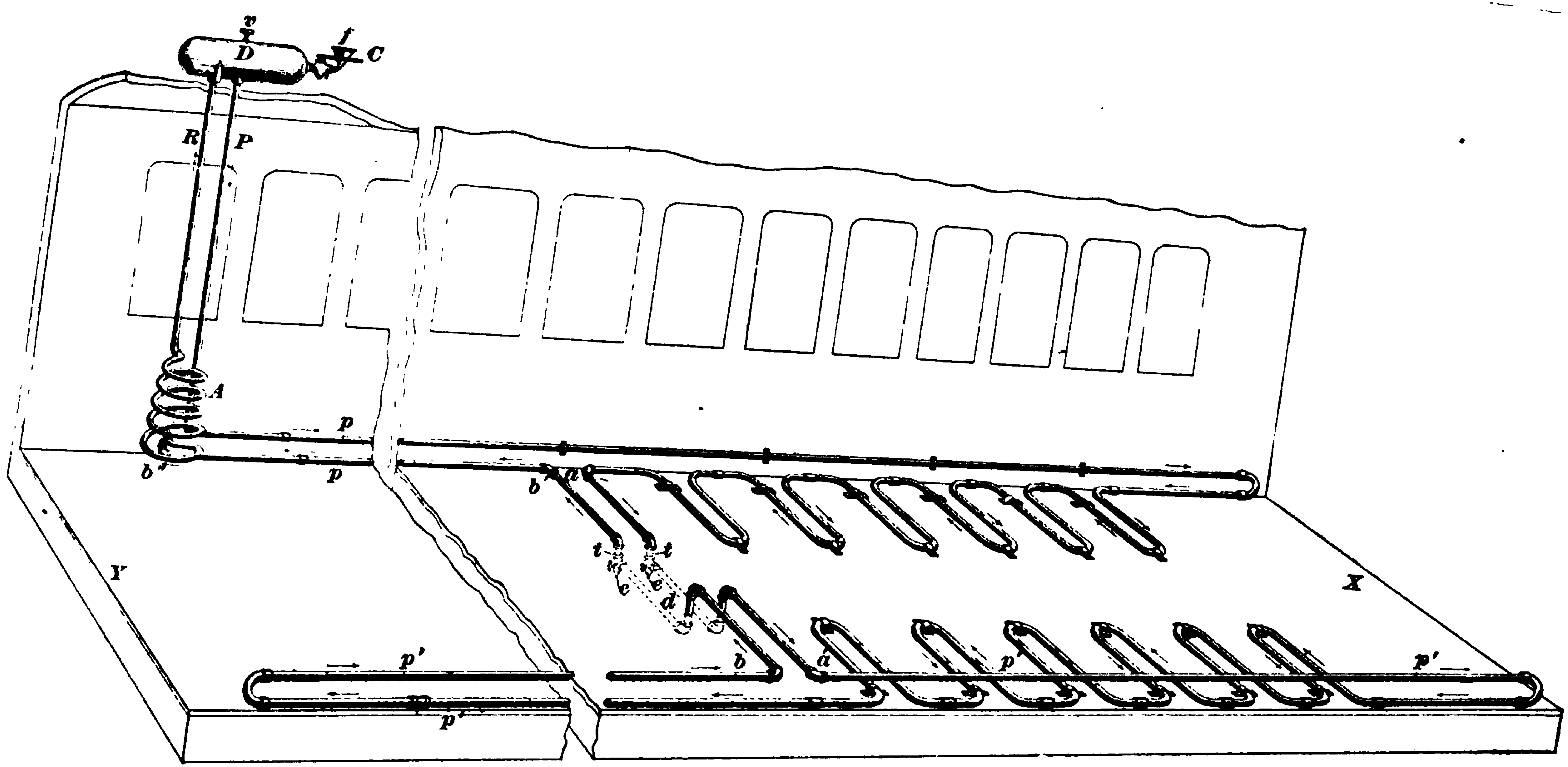


FIG. 8.

Encountering the heated pipes in the fire, the cool water is again heated, rises up through the coil and into the drum, and is again discharged out of the other pipe leading from the drum to the radiating piping. In this way a constant upflow of hot water is maintained through the coils into the drum, and a downflow from the drum into the pipes in the car. This continuous circulation of the body of water distributes the heat throughout the car much more evenly than when ordinary fire-stoves are used, as when the latter are used the heat remains more or less in the immediate neighborhood of the fire.

The drum is filled through the funnel *f* and cock *C*. The funnel, after being filled, should be turned downwards so as not to collect dirt or cinders. The cock is also provided with a drip pipe. In order to secure a more rapid and certain circulation in the system, it is of importance to have the upflow pipe *R* as long as possible; therefore, the heater should be placed as low, and the drum as high, as practicable.

BAKER FIREPROOF HEATERS.

GENERAL DESCRIPTION.

7. In Art. 3 we alluded to Fig. 1 as being the latest style of the ordinary Baker heater. This term is used to distinguish that heater from the one now about to be described, and known as the fireproof heater. One of the main objections to heating cars by fire is the danger of hot coals being scattered in the event of a wreck, thus setting the cars on fire. This danger is reduced to a great extent by the use of the **fireproof car heater** shown in Fig. 4.

In Fig. 4, *D* is the **fire-safe.** The construction of this safe is as follows: The outside shell or casing is made of a flexible grade of steel, and is without seam or joint; the depth of this shell is from *a* to *a*, as shown. Next to this shell on the inside are placed sheets of asbestos. Inside of this asbestos is a sheet-iron casing *C*, enclosing the generator coil *A*; between this casing and the coil is an air space, which accommodates the hot gases of combustion. The space enclosed by the coil serves as the fire-chamber. Thus, the fire in the heater lies within four casings:

(1) A water casing, so to speak, formed by the close-wound pipe coils filled with water; (2) a sheet-iron casing; (3) an asbestos sheeting; and (4) an outer casing of steel plate.

The only open communication between the fire and the outer air is through the small holes in the draft, or ash-pit, door *K*; if the heater should, in a wreck, have the smoke-flue base *G* unshipped, the fire could only escape through the small holes in the top *E*, and these holes are smaller than the smallest size of coal intended to be used.

In Fig. 4 a part of the **smoke screen** *N* is seen. This is a cone-shaped casting, open at the front where the coal is fed in, this opening being just behind the feed-door, of course; the coal passes down through the bottom of the casting, and through the **coal feed-chute** *o* into the fire. This hole in the bottom of the screen is closed by the **safety plate** *F*, which is controlled by the hand lever *h*, the latter being held in place by the spring *i*. The top of the screen contains small holes, as shown, for the smoke to pass through.

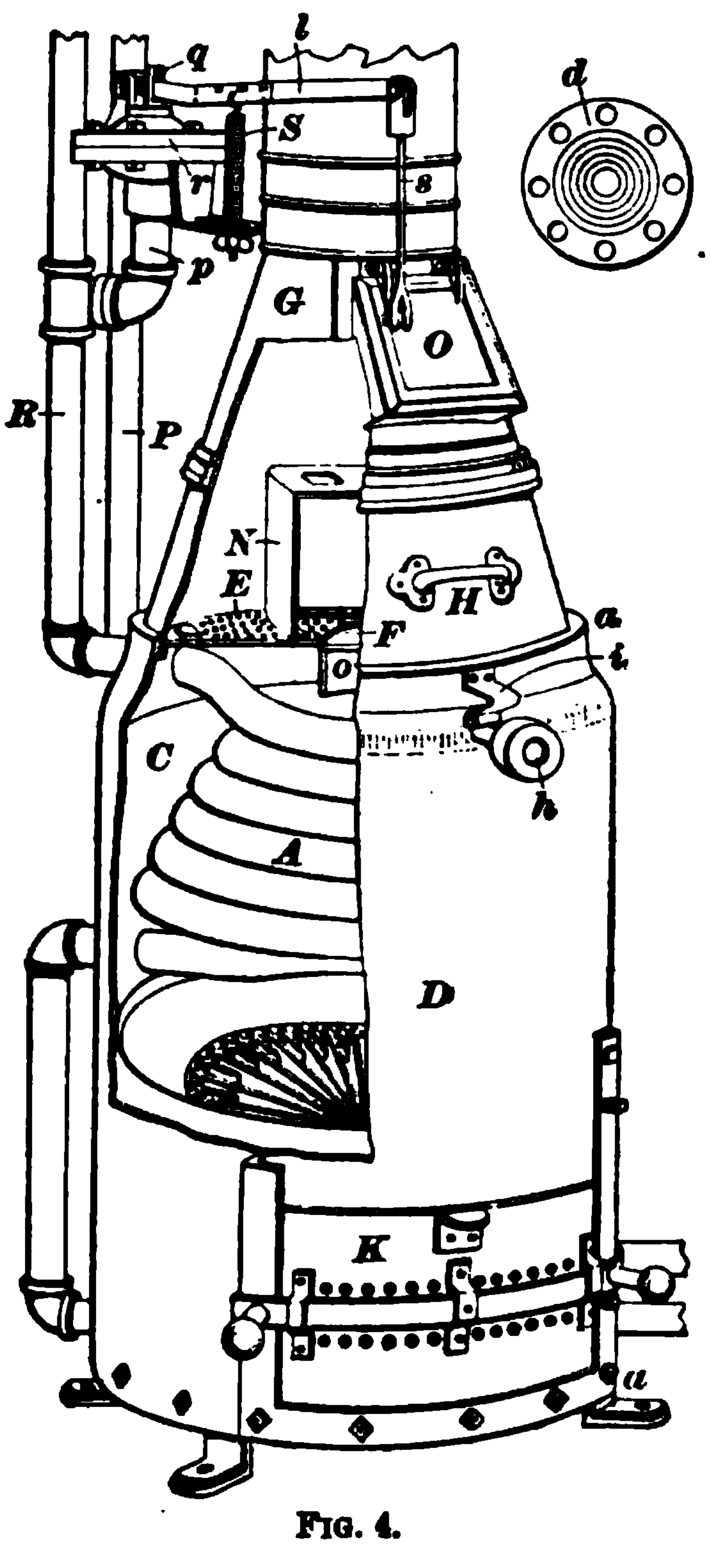


Fig. 4.

8. As to the extent to which this heater is actually fireproof, we may note that the fire is surrounded by asbestos sheets on the sides, while as to the top the feed-chute is covered by the safety plate, and as to the bottom the ash-pit is closed by a cinder-proof door. In addition, there is asbestos sheeting between the ash-pit bottom and the sheet-iron bottom of the heater. Thus, the smoke pipe and smoke-flue base might be broken off in a wreck, and yet leave the fire-chamber practically fireproof.

There is also in use the **two-coil** fireproof heater. With this heater there are two distinct circulations, one on either side of the car, thus doubling the capacity of the heater.

REGULATING THE HEATERS.

9. Description of Regulator.—The fireproof heaters just described are fitted with an arrangement for automatically regulating the fire according to the pressure in the heater and, therefore, the temperature in the radiating pipes. This draft regulator is marked *r* in Fig. 4. A pipe *p* leaves the riser *R* at the point shown and runs into the regulator bowl, which is made up of two concave pieces bolted together. In between these two parts of the bowl is a corrugated steel diaphragm *d*, shown separately at the right of figure. This diaphragm is of tempered steel and has a thin copper sheet on both sides of it—of exactly the same shape, of course—the whole being bolted in between the parts of the regulator bowl as described. The underside of the diaphragm is exposed to the pressure that is in the pipe *R*. The rod *q* passes through the top of the bowl and rests on top of the diaphragm *d*.

10. Action of Regulator.—As the pressure in *R*, and therefore in the bowl, increases, the flexible middle portion of the diaphragm is forced up, lifting the rod *q* against the action of the spring *S* and the lever *l*, thus raising rod *s* and lifting the counter-draft door *O*, which thereupon checks the draft through the fire. As the pressure in *R* falls, the diaphragm moves downwards, the spring *S* pulls the lever *l* downwards and closes the door *O*. The effect is then to cause more draft through the fire, and thus make it burn more briskly. This spring has a loop in its upper end, which may be placed in any of the holes shown in lever *l*. The nearer it is placed to *q*, the less will be the force on the diaphragm necessary to raise *l*. Each hole is marked with the corresponding pressure in the heater, that is, the pressure at which the door will be open to check the fire when the spring is in that hole. As the temperature varies with the pressure, it is seen that *r* is therefore really a temperature regulator, which is the feature required.

MANAGING THE APPARATUS.

FILLING THE PIPES.

11. General Instructions.—The water used in this heating system is salted water, or **brine**, the purpose of this being to prevent the pipes freezing in cold weather when not in use. If fresh water were used in the apparatus it would freeze at a temperature of 32° F.,* and constant danger and annoyance would ensue when starting up the fires again. Salt water has a much lower freezing point than fresh, and the more salty it is the lower the temperature at which it freezes. Care must be taken, of course, to see that the right degree of saturation is attained—in other words, that the water is salty enough. With the brine properly prepared, the pipes and fittings will not freeze even if standing for days together with the fire out and the thermometer 30° below zero. Salt water will not injure the heater pipes, as evidenced by the examination of car systems that have been taken apart after many years' service, and found to be quite free from rust or salt deposits. When about to fill a car, have a barrel or other vessel of brine prepared beforehand. In it put an extra amount of salt over and above what immediately dissolves, and then keep stirring it up from the bottom occasionally; after standing 12 hours the excess of salt will be at the bottom and clear water above. If only this clear salt water is used, there will be no deposit formed in the pipes, and at the same time the water will be salty enough to stand a very low temperature without freezing.

12. Method of Filling.—There has been much discussion as to the proper methods of charging empty Baker heater pipes with salt water, and many different plans have been adopted, some of which do not produce the absolutely solid body of water in the pipes that is essential to proper circulation. In order to secure this solidity of water, all air, dirt, and scale must be expelled from the pipes, which must be filled with

*The sign ° stands for degrees and *F.* for Fahrenheit. Thus, 32° F. means 32 degrees on the Fahrenheit scale.

water that is free from air bubbles. The plan here given has proved a good and sure method.

Open all draw-off or drain cocks in the circulation piping, remove the safety valve, but keep the combination cock closed, and run from the topmost tapping in the expansion drum a $\frac{1}{2}$-inch pipe, as shown at *A A*, Fig. 5. This piping must be made up so as to be absolutely tight. Extend the $\frac{1}{2}$-inch pipe downwards toward the ground outside the car, and connect it to the upper end of a coil of pipe in a barrel or tank, the latter being located as close to the car as convenient.

This coil *B* is made of $\frac{1}{2}$-inch pipe, and should be made up about 2 inches smaller in diameter than the inside of the barrel, and coiled as closely as possible, so as to get in a large amount of heating surface. Near the lower end a T fitting *a*, view (*b*), is used, and an angle valve *b*, view (*a*), is connected to the T, as shown. In order to prevent the salt or other solid matter getting into the pipes, a metal strainer *c* is attached to the angle valve. A convenient form of strainer is illustrated herewith, but any form will do, provided it has at least twenty-five $\frac{1}{8}$-inch holes in it. The lower end of the coil is connected with the globe valve *e*. The angle valve *b* is provided with an extension handle that reaches above the top of the barrel. View (*b*) shows the lower portion of the coil, with the angle valve and strainer in position, as seen if viewed from a position opposite the valve *e*.

Fill the tank with the brine or fresh water (brine preferred) with which it is desired to fill the pipes. The brine should contain a considerable amount of undissolved salt over and above that which the water will take in solution. The water in the barrel must, of course, be sufficient to fill the pipes without drawing the level in the barrel down too near the strainer. At no time should the water level be less than 4 inches above the strainer. One hundred feet of $1\frac{1}{4}$-inch pipe contains about $7\frac{1}{2}$ gallons of water; so, if the number of feet of circulation piping is known, the water necessary is easily calculated. An excess of at least one-third should then be allowed for as a measure of safety. An ordinary barrelful of water will suffice for all ordinary cars, or for each half of a double-circulation

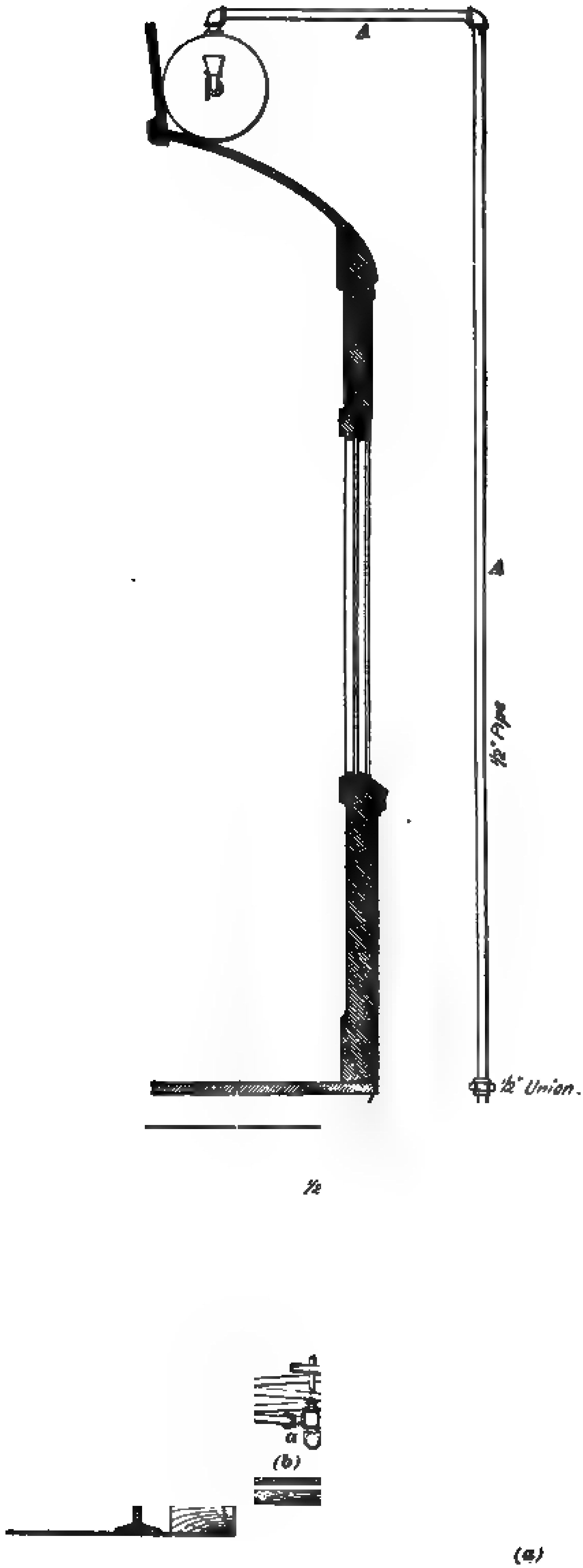


Fig. 4.

car, but it is well to have an extra amount on hand to use in case the water level in the barrel should be lowered too near the strainer, otherwise air might be taken into the system.

Close the angle valve *b* and open the globe valve *e*. Connect a steam hose to the draw-off cock furthest from the expansion drum, and blow about 25 or 30 pounds of steam into the pipes. As fast as it issues freely and in full volume from each open draw-off cock, close that cock. In a very few minutes every foot of the heater pipes will be full of live steam, as will be indicated by the temperature of the pipes, and the steam will force its way up into the expansion drum and out through the coil *B* and the globe valve *e*. It carries with it the air that has collected in the pipes, and this, together with the water of condensation, will be discharged from the globe valve *e*. If live steam escapes with the water, close the valve a little, or until only water and air escape.

After the air is expelled, the steam heats the water in the barrel to the boiling point. This act of boiling expels the air that is always in suspension in any body of water not boiled; when the water in the barrel is salty enough to float a potato while boiling, it is suitable for use in the circulation pipes.

Close the globe valve outside the barrel and the draw-off cock through which steam enters the pipes; also, disconnect the steam hose. Then open the angle valve inside the barrel. The steam issuing from the pipes now escapes into the brine in the barrel, and continues to escape into it until the pressure reduces. The steam remaining in the pipes condenses and forms a vacuum, into which the boiling-hot brine from the barrel is forced by atmospheric pressure, and, if the work has been carefully done, in a very few minutes the pipes will be completely filled. This will be indicated by the level of the water in the barrel becoming stationary.

The ½-inch piping can now be disconnected, and the drum will be found full to the top. Draw it off, through the combination cock, to the level of this cock, and replace the safety valve. After standing for some hours, the water, having cooled, will contract to some extent, and a small amount of water may

then be added by hand through the combination cock. The heating system is then ready for service.

Double-coil circulations require two separate treatments, just as if they were two separate cars.

FIRST FIRING UP.

13. Build a light wood fire, and fire up slowly until the circulation of hot water is complete, which may be known by the piping being hot all the way around the car and back to the bottom of the coil. Then allow the fire to go down and the pipes to cool off. It may probably require two or three firings and subsequent coolings before the air is all exhausted from the pipes and the water "solid." After the first firing, it will, as a rule, be found that the heater will take in considerable more water. This matter of renewing the water should be carefully looked to for the first few days; a slight deficit may have to be made good each day for the first week or so. When once the water has become solid throughout the heater and pipes, any further renewal of it will be seldom found necessary; still this point should be tested from time to time to make sure that everything is right.

TESTING, RENEWING, AND DRAWING OFF THE WATER.

14. Testing the Water.—When testing the water, that is, ascertaining the amount in the heater and piping, the fire must be low and no pressure in the heater. The test is made by noting the height of water in the drum, which is done by means of the combination cock *C*, Fig. 2. If the water is at the right height, it will run out of the drip pipe when the cock *C* is opened.

15. Renewing the Water.—If found necessary to renew the supply of water in the system, it may be done by putting water in through the filling funnel *f* that is attached to the cock *C*. After renewing the supply of water, close the cock *C* and turn the funnel down.

16. Emptying the Heating System.—Occasions sometimes arise when it is necessary to empty the water from the

heating system. To do this, draw off the water through the cock *e* in the crossover pipe, Fig. 3, observing at the same time to open the cock *C* in the drum to act as an air vent—that is, to let in atmospheric pressure for the purpose of assisting the water to flow out more readily. If there is an extra drain cock in any location where water can be pocketed in the piping, open such cock and drain off the water. The system should not be emptied unless it is absolutely necessary, as for instance, in the case of repairs.

LOW WATER.

17. As long as the water is kept solid in the pipes and is maintained at its proper height in the drum, the circulation will be satisfactory throughout the whole system without having any pressure in the heater. If, however, the water is allowed to get low enough to leave the drum empty, circulation will stop, the pressure will mount up, and the safety vent probably blow out. If the water is allowed to get so low as to leave the coil, the latter will burn out.

In case of a safety vent blowing out, the fire must be drawn at once; the water should then be renewed, so as to come up to the level of the combination cock *C*, another vent *v* screwed into the drum, and the fire relighted.

CONDITIONS AFFECTING CIRCULATION.

18. When the heating system is working properly, the water in the heater coils, risers, and radiating pipes, forms one continuous body that keeps circulating around the car, the motive power being the heat in the fire around the coils *A*, Fig. 3. This heat, in passing through to the water in *A*, heats the water and causes it to rise, and the cool water below, which comes through the return length of pipe, takes its place. At the same time this cool water in the pipes is replaced by hot water from the expansion drum. The cool water that has just come into the coils is in turn heated by the fire, and then rises and passes up *R* into the drum; it then goes down *P* and around the system once more. The circulation is aided and rendered continuous by the force exerted by the compressed air in the air

chamber—that is, in the upper part of the drum. The pressure therein is due to the following cause: When the system is cold, the space in the pipes is fully occupied by water, and the upper part of the drum by air. We assume the system to be in good working order, and the pipes therefore to contain no air. When the fire is lighted and the water in the coils heated, this water expands and occupies a larger volume. Water itself is practically incompressible, while air is compressible to any extent; therefore, the only way in which accommodation can be provided for the heated water is by the air being compressed in the drum. This is what happens, and in being so compressed the air exerts a reactionary pressure on the surface of the water and so forces it down pipe *P* into the circulating system. The principal impediments to this easy flow that are likely to arise in a heating system are: (1) Neglect to maintain the water at its right height; (2) pressure of air trapped in the piping; (3) obstruction in the piping; (4) too great a length of piping; (5) too many turns—elbows, bends, etc.—in the piping.

SAFETY VENT.

19. On the old-style Baker heater, the safety appliance consisted of a rubber ball held between two brass plates. The screws holding these plates must be left as they were originally; that is, the plates must not be screwed any closer together than intended. Every time this ball valve blows off it spoils this ball; therefore, a new one should be put in. The cast-iron safety vent, however, is more reliable.

TESTING THE CIRCULATION.

20. It can be ascertained whether the circulation is going on properly or not by feeling the pipes near the heater. If the riser *R* and downflow *P* are hot, while the pipe *p*, where it enters the stove after making the circuit of the car, is cool, then the system is working properly. If, however, the circulation is stopped, the pipe *p* near the heater will get hot and the pipe *P* will get cool. If a car is found to be cold, first examine the fire, and if that is going all right, test the circulation. To do

this, feel of pipes p, R, and P. If pipe p is cool and pipes R and P are hot, there is circulation, and it will not be necessary to dump the fire. If this has stopped, put out the fire for fear the system should be short of water, and the heater coil therefore be in danger of burning. Then, if the weather is severe, rendering the prompt renewal of heat imperative, renew the water in the drum at the next station stop, first allowing the steam to escape out of the filling cock C. If the drum is found to be very hot, take out the safety vent and pour in cold water until the drum is half full. Then replace vent, turn down the filler, and restart the fire. If the circulation does not now commence, there may be an obstruction in the crossover pipes. Try the effect of a sharp, sudden blowout, opening the cocks fully, but losing not more than a quart at each cock, or else the water in the drum will be lowered too much. If the circulation still fails to start, draw the fire and empty all water out of the car, letting it drain out while running, opening the funnel on the drum to let air in to assist the emptying process.

MANAGING THE HEATER.

21. Starting the Fire.—In starting the fire, use wood not over 2 inches thick, and have plenty of it at hand for the purpose, so as to have the fire start quickly. Light the kindlings first, and check the draft so as not to get too sudden and sharp a fire. When the fire has a good start, add the coal gradually, and afterward keep the fire-pot full.

In starting a fire, one may feel assured that the heater is working well if the lower pipe is cool close to the place where it enters the fire. This should always be the coolest part of the piping; and the top pipe, where it leaves the fire, should always be the hottest part. When the heating system is at its best, the piping will be hot all around the car without there being any pressure in the system.

22. Management of the Fire.—Hard coal, clean and free of slate, and of the proper size, should be used. If the coal is too large, pieces will lodge against the coils instead of

settling down on the fire-grate. Keep both the feed-door and the ash-pit door closed, except while starting the fire. Cool or check the fire by opening the feed-door; that is, the upper door. Never have both doors open at the same time; nothing can of course warrant such a proceeding, as the one counteracts the effect of the other. Never go away and leave the draft full on, nor ever let the fire go out. When the automatic regulator is in use, it should be properly adjusted to suit the weather, and then the fire itself can be left to control the draft. During such times, as when little or no heat is wanted, unhook the spring *S* from the lever *l* and thus let the door *O* remain open; this checks the draft through the fire. Never let the fire get so low as to require rekindling, but keep a good, clean fire night and day as long as the car is in service.

The feed-door must be kept closed at all times except when putting on fuel, the ash-pit should always be kept clear, and the ash-pit door should only be opened when removing ashes and cinders.

The feed-chute should be kept well filled with fuel, the fire burning well and kept clean below. Shake the grate only when the fire shows dark underneath. With the Perfected and Midget heaters, the grate is shaken through the slot in the ash-pit door; in the fireproof heaters, the ash-pit door must be raised for that purpose.

The **safety plate and gas preventer** is located over the fire-chamber; it must be kept fastened down at all times except when putting on coal. Its duty is to prevent any fire from spilling out in case of a collision or wreck. It is also intended to prevent coal gas from escaping into the car. In the fireproof heater, Fig. 4, this safety plate *F* is placed under the top head of the heater, over the fire. It must always be left closed after firing, etc.

PRESSURE GAUGE.

23. The function of the **pressure gauge** is to indicate the pressure within the heater. Thus, the figures 10, 20, etc. on the dial refer to pounds of pressure. If the heater is in good order, and the instructions herein given for its management are

faithfully followed, no excessive pressure can result. Attention is directed to the fact that the less the pressure at which the heater can be operated, the better.

SUMMARY OF INSTRUCTIONS.

24. The whole of the foregoing instructions as to the fire and water in this system may be condensed into two rules, the strict observance of which will, in any of the heaters here dealt with, result in perfectly satisfactory working: (1) Maintain the water at the right height, and see that it is kept *solid* throughout the pipes; (2) keep up a slow, steady, constant fire.

THE GOLD SYSTEMS.

GENERAL SCHEME.

25. In the Gold Company's systems, steam is allowed to pass from the boiler of the locomotive into a line of piping running the whole length of the train, the connection between the cars being made by hose couplers. The steam supply is regulated by a valve under control of the engineer. The main piping, called the **train pipe**, runs centrally underneath the cars, the connection between the cars being made by hose couplers, as already stated. From this pipe each car receives its supply of steam, the steam passing into a system of piping running along near the floor on each side of the car.

ENGINE EQUIPMENT.

26. Fig. 6 shows the arrangement of the **engine equipment.** Steam is usually taken from the dome of the boiler, as shown, the supply being controlled by the angle valve V, the pressure regulator being shown at R. One-inch pipe is used, both piping and fixings up to this point being of extra heavy quality.

Gauge G indicates what steam pressure the regulator is delivering to the train. From the regulator the steam is carried by suitable piping P to the rear of the tender, where it connects with the train pipe.

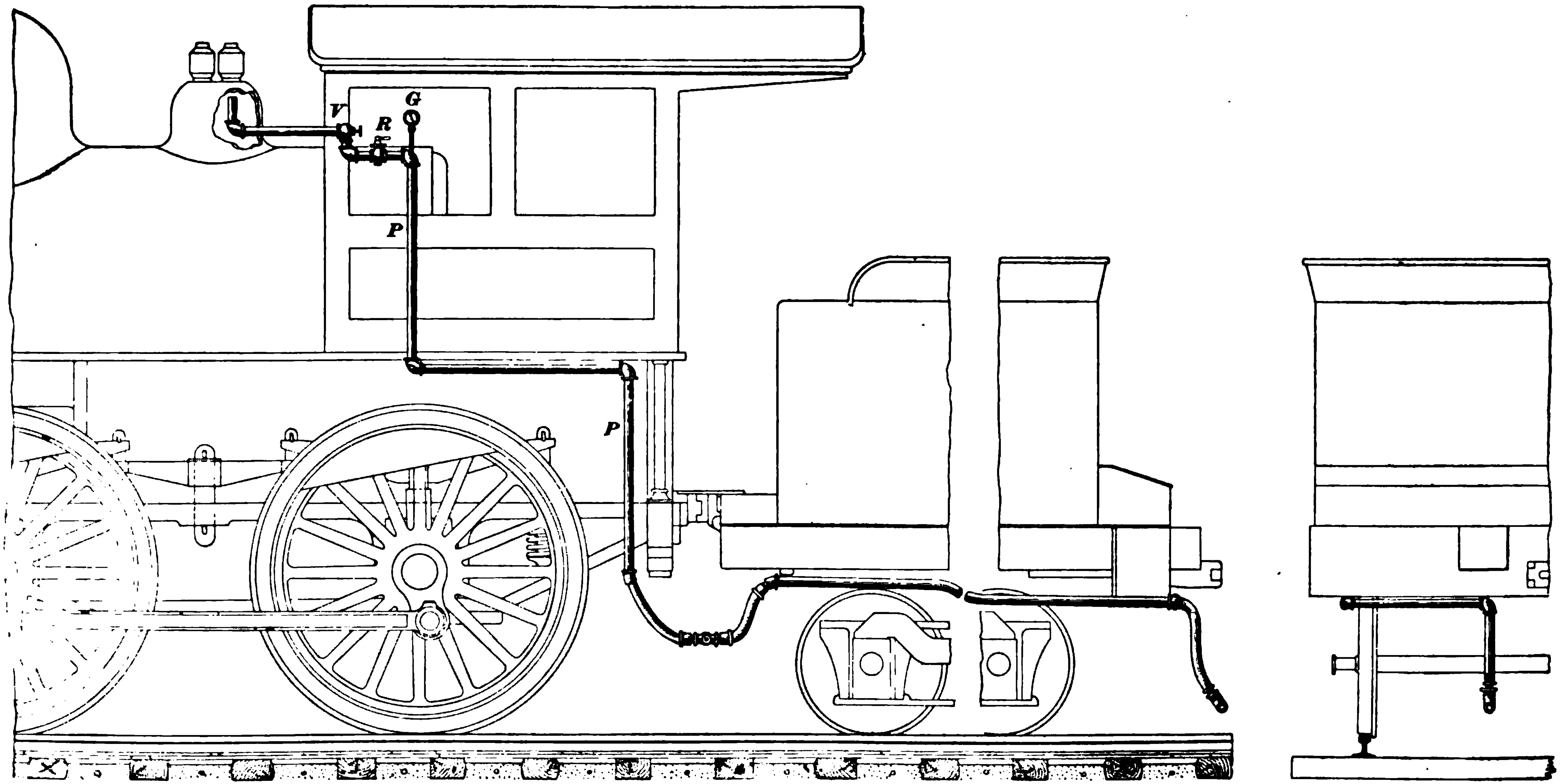


FIG. 6.

STOP-VALVE.

27. In Fig. 7 is illustrated the **stop-valve** used in connection with the Gold system of train heating. It is an ordinary hard-seat valve, and needs but little description. The valve *A*, which is ground on to its seat, is carried by the valve stem *B*, which is operated by the wheel handle *C*. The pipe that brings the steam supply from the boiler connects at *D*, while the pipe that leads to the regulator connects at *E*, being tightened up on to its seat *F* (which is a ground joint) by the union *G*. By means of this valve, the engineer can shut off the steam from the train altogether when desired.

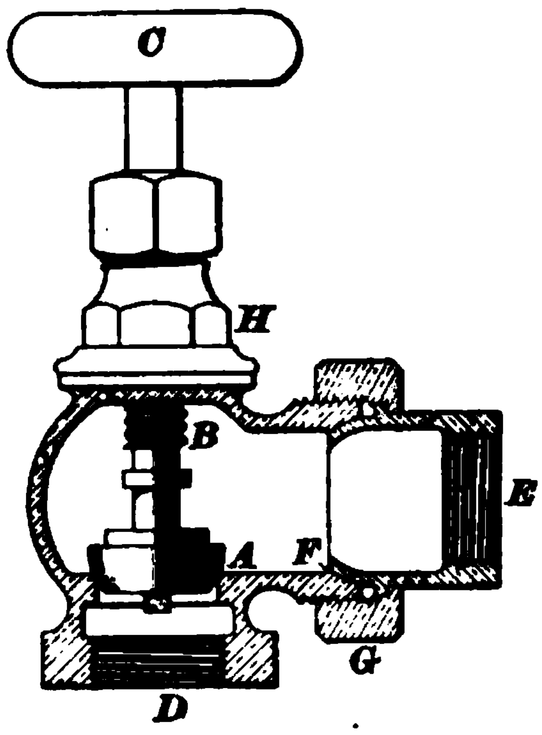


FIG. 7.

PRESSURE REGULATOR.

28. Description.—Fig. 8 shows a sectional view of the pressure regulator used in the Gold system. Steam from the boiler enters at *A* and leaves at *B*, the connection being made by heavy brass unions *U*.

The valve that controls the passage of the steam consists of the disks *a* and *b* carried on the spindle *C*. This stem is pressed down by the spring *F* acting on the flanges *E* and *D*. Between these flanges is the diaphragm *G*, the outer edge of which is secured between the dome *H* and body *I* of the regulator, as shown. This diaphragm is a solid sheet of some special metal; provision is made against any undue straining of it by widening the flange *E*, so that the diaphragm always maintains practically its original condition. The recess *r* provides a water seal and thus prevents chattering.

The regulating is done by means of the handle *J*. When this is turned around, the hollow screw *K* moves up or down, and with it the top spindle *L*, thus relaxing or tightening up the spring *F*. When once set for the proper pressure, the

handle J is locked in position by the nut and handle N. The setscrew M can be screwed in or out independently, and serves for a check on the maximum or minimum pressure

Fig. 8.

required, for it can be set to control the movement of the spring F by coming in contact with the top of spindle L. The bottom plug O helps to guide the spindle C, and the lower

spring f keeps the valve $a\,b$ closed except when handle J is screwed down to open it; this spring also makes the valve respond promptly to the movements of the diaphragm.

29. Action.—Suppose the boiler pressure is 200 pounds, and it is required to supply steam of only 30 pounds pressure. On the steam being admitted into A', it finds the valve $a\,b$ closed, that being its normal position—due to the thrust of spring f as already explained. By now turning the handle J from right to left, the valve $a\,b$ will be opened, and steam will flow into B' and so on through B into the train system, reducing the pressure therein to the desired amount, as indicated by the steam gauge. The steam in B' also passes up to the under side of diaphragm G and flange D, tending to force these upwards. Directly the steam in the train system and chamber B' has risen to slightly above 30 pounds pressure, the pressure of the steam underneath the flange D and the diaphragm G moves them upwards against the force of spring F, the valve following, being pushed by spring f. If, now, more pressure were required in the train, the spring F would have to be screwed down so as to increase its thrust, and hence the steam from B' would not force the diaphragm up and allow the valve to close until it had reached a higher degree of pressure. Suppose, now, that the steam in the boiler fell to, say, 170 pounds; this would not affect the pressure in B' and the train, for the latter pressure would not allow the valve to close until it had attained the required degree—say 30 pounds.

30. Using the Regulator.—The regulator is opened by turning the handle J from right to left, and, when opened to the proper amount, it can be secured in that position by the device N. The regulator must not be used as a stop-valve, that is, for the purpose of shutting off the steam from the train entirely. The angle valve shown in Fig. 7 is provided for that purpose. The regulator is intended merely for the purpose of reducing the boiler pressure down to the proper pressure required in the train, and this is done by turning the handle J until the pressure on the outlet side B' is of the

proper amount, as shown on the gauge provided for that purpose. If more pressure is required on the train, then the handle *J* must be screwed farther down, that is, turned from right to left. If less steam pressure is required, the handle should be turned in the opposite direction, namely, from left to right; when the proper position is reached, lock it there by means of *N*.

The valve stem *C* may be withdrawn occasionally for inspection and cleaning. To do this, ease the pressure of the spring *F* by turning the handle *J* from left to right, take out the bottom plug *O*, and then withdraw the stem. See that the spring *f* is clean and working properly on the stem, and also that the recess in *O* is clean. By taking off the nuts *P*, the dome *H* may be removed and the parts inspected, attention being paid to the recess *r*.

HOSE COUPLERS.

31. Fig. 9 (*a*) shows a set of **hose couplers** as connected up in position on the train. View (*b*) shows the manner of coupling up, and is a view of the couplers from above, showing them in the act of being brought together, the two gaskets *g* just coming in contact. This hose coupler is provided with a **gravity relief trap,** the trap as a whole being in a horizontal position when the hose are coupled up. When steam first passes into the coupler, it acts on the baffle plate of the trap

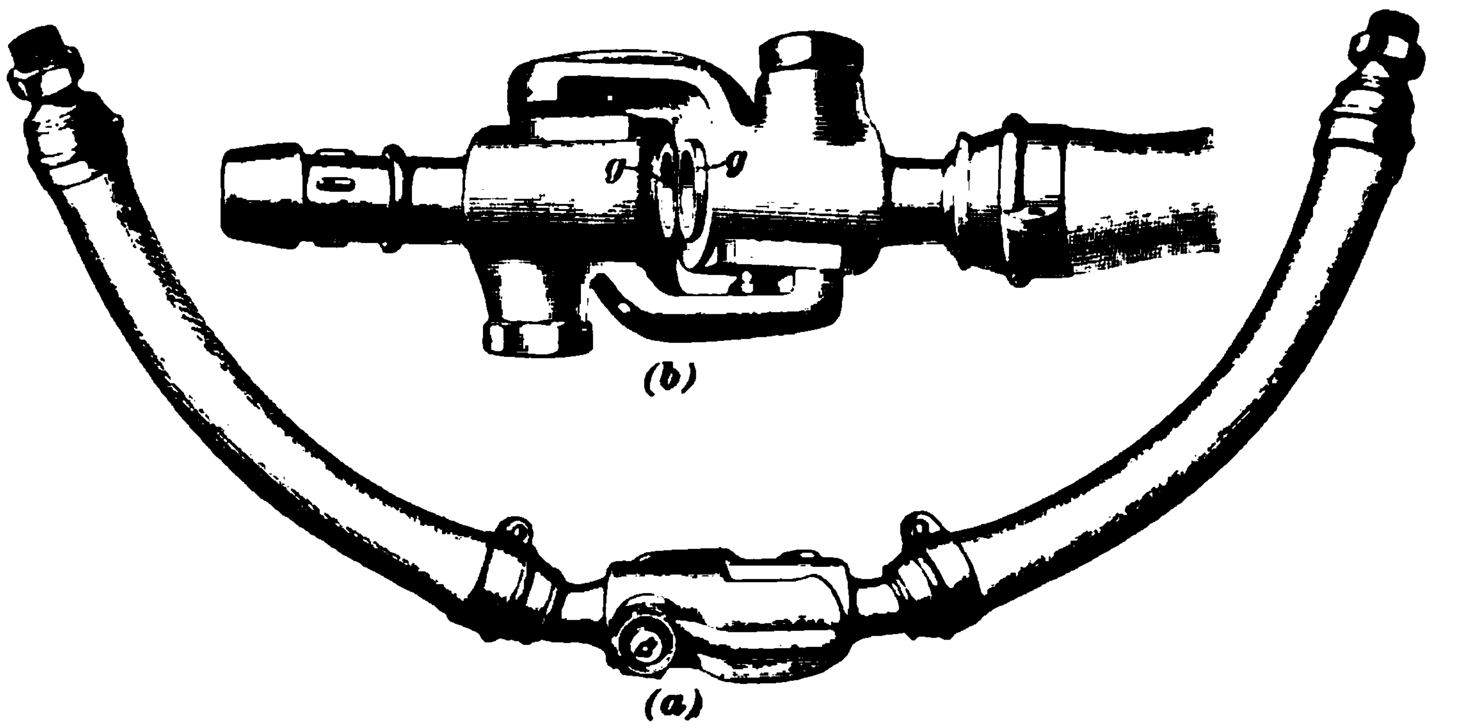


FIG. 9.

and forces the valve up against its seat, thus preventing any escape of steam. As soon, however, as the steam pressure is released, the weight of the baffle plate causes it to fall, tilting the valve and thus opening the trap and releasing all water from the coupler. When steam is again turned on, it again closes the valve. The use of a trap such as this obviates the necessity of uncoupling the cars when laid up or when steam is not in use on the train.

CAR EQUIPMENT: DIRECT STEAM.

GENERAL DESCRIPTION.

32. The **direct**, or **straight steam** system is used in the majority of cars at present equipped with steam heat. Fig. 10 shows a plan of a car floor in perspective. *P* is the train pipe through which steam from the boiler passes. Steam is taken from the train pipe by means of the train-pipe valve *V*, which can be operated from either inside or outside the car. As seen in the illustration, this valve is attached to the train pipe underneath the car, and as a rule in about the center of the car's length. At one side of this valve is a short nipple through which steam passes into the pipes P' that lead to the valves v, v'. From the side outlet of each of these supply valves runs a length of extra heavy pipe a, a' which connects by means of a heavy T piece with the two

courses of piping *p* and *p*, that constitute the radiating surface for heating the interior of the car; these pipes run alongside the truss planks on either side of the car. At one end of each course of piping is a loop *l*, the object of which is to provide for the expansion or contraction of one of the pipes of a pair relative to the other. The lower pipe of each pair is formed into a loop *L* at about the center of the car, a special return bend with side outlet being used to connect with the short vertical drain pipe *i*.

Care should be observed to give the pipes a slight pitch so as to enable water to find its way to the traps *T* and *T'*; these are placed under the car, one on each side. To protect the dresses or feet of passengers from coming in contact with the hot pipes between the seats, shields are placed over them.

The two sides of the car are independent of each other as regards their heating; each side has its own separate steam-supply valve, and also its own steam trap. Thus the heat on either side of the car is easily regulated. The supply valves are generally in the center of the car's length at the end of the seats, close to the aisle, so that they can be readily operated without disturbing the passengers. In this and following systems, the piping, valve, etc. on the two sides of the car are for the most part identical; our explanations, therefore, while alluding only to the one side, yet apply equally to the other.

TRAIN-PIPE VALVE.

33. A valve called the train-pipe valve, used for controlling the supply of steam to the individual car, is shown in Fig. 11 (*a*). The part marked *a* is the valve body, inside of which is a valve that is operated from inside the car by the socket *b*, the floor plate *c* having marks thereon to act as a guide to the valve's position; *d* is the spindle that actuates a cam or eccentric that works inside the piston valve contained inside the body *a*. This spindle has a square fit inside the socket *b*, and is also held by the setscrew *f*; the spindle *d* can be turned around by means of the handle *g*, which is fastened to the flange sheave *h* by the setscrew *i*. The sheave spring *j* is held in the arm *k* and engages with a slot in the edge of *h*.

The spindle d can also be turned by inserting a key in the top of the socket b, the key being shown in view (b); a downward

(b)
FIG. 11.

thrust displaces the plug *l* against the resistance of a spring inside *b*, view (*a*), and then the socket, and with it the spindle *d*, can be rotated. The connection with the train pipe is made by means of the union coupling *n*. Any condensation is taken care of by the steam trap, and so water is prevented backing up into the piping, where it could freeze and burst the pipes. The purpose of the train-pipe valve is to shut off the steam at the train pipe from all cars in the rear of that particular valve; it is not intended as a means of shutting off steam from its own car, as it would also shut it off from all cars behind it. The steam is shut off from a certain car by using the steam valves *v*, *v'*, Fig. 10. When changing engines, the valve can also be operated so as to shut in the steam already in the train.

END TRAIN-PIPE VALVE.

34. On occasions when it has been found more convenient to put the train-pipe valve under the platform at the end of the

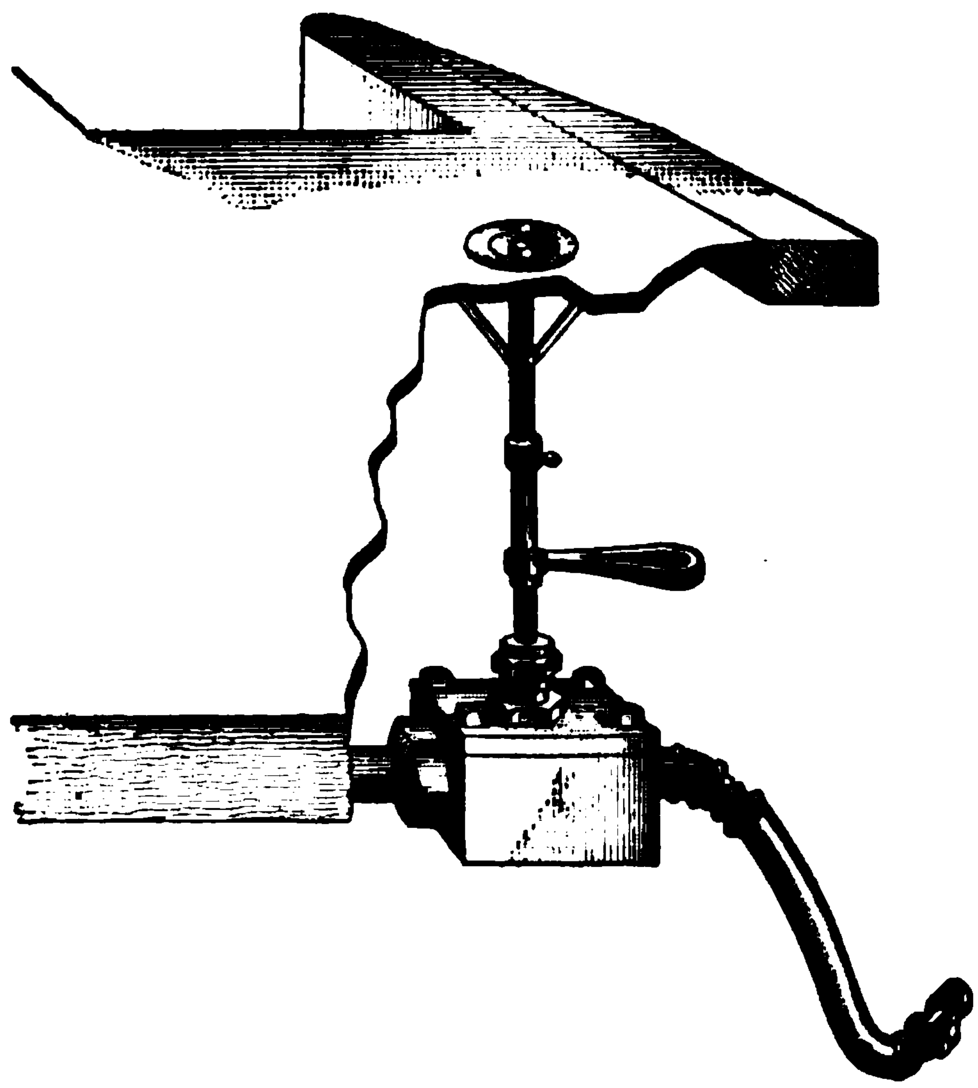


FIG. 12.

car, the design shown in Fig. 12 has been adopted. This valve is constructed on the same principle as the ordinary standard

valve shown in Fig. 11, and is opened and closed by means of the cam arrangement therein used. It is fitted with a drip to prevent freezing. The drip hole, about $\frac{1}{8}$ inch in diameter, is not shown in the figure, as it is on the far side of the valve body, as viewed in the figure.

AUTOMATIC STEAM TRAP.

35. Purpose of Trap.—It is of the utmost importance in a steam-heating apparatus that suitable provision be made for disposing of the condensed steam, so as to prevent the system from freezing and giving trouble through bursting pipes. For this purpose an **automatic steam trap,** Fig. 13, to which is attached a sediment well and a gravity relief trap, is used with this system.

36. Description.—The apparatus shown in Fig. 13 is placed at a convenient point behind the car trucks and is connected with the drip from the heaters in the car. In the figure, *a* is the body of the trap; *b*, its cover; *c*, the composition seat with which, under certain conditions, the diaphragm *d* comes in contact, being held there against the push of the spring *e*. The diaphgram is held in position by ribs or lugs on the interior of body *a* and also by the setscrew *f*, which is secured where required by the locknut *g*. There are seven of these ribs, marked *i* in the figure. One is directly opposite the outlet, and so is shown cut through.

The part marked *h* is the ventilator, the interior of the trap communicating with the atmosphere through the notched openings *j*, a piece of gauze wire *k* being placed inside, as shown, to serve as a strainer. The inlet and outlet are as marked. This ventilator is for the purpose of keeping the trap cool.

The interior of the diaphragm *d* is partially filled with an expansive fluid, which is very susceptible to changes of temperature, expanding and contracting as the heat in the trap rises or falls. This diaphragm is now made so as to reduce the probability of leakage to a minimum. When it is required to clean or repair this trap, simply remove the cover *b*, which locks by means of its lugs engaging with the inclined flanges, not here

Fig. 12.

shown, on the body *a*. A quarter turn will remove the cover, and the same amount will lock it tightly in position again.

37. Action of Trap.—When the trap is cold, the fluid within the diaphragm contracts and the diaphragm occupies the position shown in the figure, thereby enabling the spring *e* to force it away from its seat *c*. When all the condensed water has been discharged and live steam comes in contact with the diaphragm, the latter is caused to expand again and thus come in contact with the seat *c*, thereby closing the trap and preventing a waste of steam. As condensation continues, and the water thereby formed gets colder, the trap again cools off, the fluid within the diaphragm contracts, and the diaphragm is again moved back to the position shown, allowing the condensed water to pass off through the outlet *x*. When used for draining off the condensation from the heaters within the cars, this trap is provided with a sediment well having a gravity relief trap *t*, attached as here shown. The duty of this sediment well *l* is to retain any dirt that might otherwise be carried over into the trap and clog up and impair the seat. The partition *m* is so located as to intercept the dirt, the latter then dropping to the bottom of the well. The sediment thus collected should be blown out two or three times during the winter. This may be done by opening the valve *u* by turning either handle *w*, or the handle *w′* operated from inside the car, according as to which is most convenient. This valve *u* is provided with a composition seat; when closed, it screws down on the threaded brass plug *n*, which forms a seat for it.

VERTICAL STEAM TRAP.

38. Description.—It has sometimes been found desirable to use traps that shut off the condensed steam within the car body; in such cases the trap shown in Fig. 14 is used. The trap is placed in a vertical position, with the cast-iron trap head, which contains the automatic valve, inside the car, the body of the trap extending down through the floor, as shown; the expansion device is at the bottom of the trap, and when the

latter is placed in position in the car, the part containing this device comes inside the car. The amount of expansion that must take place before operating the valve is adjusted by means of the screw *f* and the locknut *g*; this, when once regulated, needs but little subsequent attention. The blow-off valve *w* is provided so that when so desired this apparatus and the heating system may be quickly relieved of pressure or of condensation. The valve may be removed by unscrewing the bonnet *x*. The trap is provided with a hinged cover *m*. The purpose of this trap is to release all the condensed water automatically, prevent freezing, and keep steam in the inner coils as dry as possible.

39. Action of Trap. The action of the trap is as follows: When steam is shut off, and the trap is therefore not in operation, the diaphragm *d* is in its contracted condition, that is, has shrunk to its smallest bulk, and the valve *c* therefore has fallen away from

FIG. 14.

its seat. When steam is turned into the heating pipes, the water that is in them is released through the valve and flows down and out through the openings *h*, *h* in the bottom of the trap. As the temperature of the outflowing water increases, the liquid in the diaphragm *d* is heated and expands, causing the diaphragm to swell and thereby raise the rod *s* that pushes the valve *c* up to its seat again. The flow of hot water on the diaphragm thus being shut off, the liquid in the diaphragm cools again, and so allows the walls to come together, thus letting the valve rod *s* fall and release the valve *c* from its seat, permitting the escape of the condensed water that has meanwhile accumulated.

OPERATING THE SYSTEM.

40. Working the Train-Pipe Valve.—In view (*b*), Fig. 11, is shown a plan view of the floor plate *c*, showing also the top of the socket *b*. A groove *z* is cut in the upper surface of the socket, and three others in the floor plate. The valve is moved by rotating the spindle *d*; the socket and spindle move together. Hence, when the valve moves, its positions are indicated to the trainman by the position of groove *z* relative to the grooves in the floor plate. The front and rear of train being as here shown, we will allude to the two "shut" grooves as *f* and *r*, respectively. Then, if it is desired to shut off steam from the cars in the rear of the one whose train-pipe valve we are supposed to be operating, or if this is the rear car, groove *z* must be brought in line with groove *r*. If steam is required to pass through to the rear cars, *z* will stand as in Fig. 11 (*a*), in line with the "open" groove.

When it is desired to retain the steam in the train, as, for instance, when engines are being changed, the groove *z* on the first car must be brought into line with the groove *f*, the groove nearest the engine. When turning the indicator toward the word "shut" in either direction, turn it as far as it will go, even if it should thereby go past the groove. The letters *z*, etc. are not on the actual apparatus; they are used here merely for convenience of reference.

41. Heating a Cold Train.—First see that the train-pipe valves are open on all cars except the rear one; if the train-pipe valve on this car is open, close it. It is advisable, although not strictly necessary, to have all the steam valves under the seats closed, except those in the rear car. This being done, let a good pressure of steam—say 50 to 75 pounds—blow through the train pipe until it shows at the rear car. Next open the steam valves under the seats from the rear of the train toward the engine, and then tell the engineer to reduce pressure. When once the pipes in the train have all been filled with steam, from 10 to 20 pounds pressure on each car will ordinarily be sufficient to keep them perfectly warm.

42. To regulate the heat in moderate weather, or whenever necessary, close one or both of the steam valves under the seats. These steam valves should always be open at least three turns, or else be closed tight. Shutting off the heat in any one car does not affect the heat in any other car. Whenever a car is laid out, **all valves should be left wide open.**

43. Coupling Up and Uncoupling Cars.—When coupling the hose of two cars together, it is advisable to tip the coupler bodies up evenly, so that both sides shall lock at the same time and the gaskets come up fair against each other. When uncoupling the hose by hand, pull the coupler bodies straight up in the middle, where they join together.

44. Operation When End Train-Pipe Valves Are Used.—As before, when about to heat a cold train, see that all the train-pipe valves are open, and then send a good pressure through the train. When it blows out strong at the rear, close the rear train-pipe valve, allowing a slight escape of steam.

Regulate the heat, according to requirements, by the steam valves, as already explained. The blow-off valve on the trap should always be closed when the supply valve is open. After the pipes in the cars are filled with steam, the pressure from the engine may be reduced according to length of train and state of weather.

When approaching a terminal where the engine is to be cut off, open the rear valve and signal the engineer to shut steam off from the train.

CAR EQUIPMENT: HOT WATER.

(SYSTEM 1.)

GENERAL DESCRIPTION.

45. The Duplex Coil.—In the system we are now about to describe, the heating is done directly by hot water, the water being heated by steam from the engine as before, a Baker heater being used for this purpose (see *S*, Fig. 15). A compound or **duplex double-pipe coil,** however, is placed in the heater instead of the regular Baker coil. This duplex coil is made up of two 2-inch pipe coils *A* and *A'*, inside each of which is a coil of $\frac{3}{4}$-inch pipe, as shown in Fig. 15, where part of the heater casing *S* is shown removed so as to expose the coils to view, the pipes composing the larger of which are also shown broken away partially, exposing the $\frac{3}{4}$-inch inner coils. These coils are fitted at the ends with special T pieces *t* and *t'*. In the upper openings of the T pieces *t* are screwed the pipes *R*, *R'*, leading to the expansion drum *D*, while the lower T pieces *t'* connect with the hot-water pipes that run around the car.

46. The Car Piping.—The course of the steam is as follows: Steam is taken from the train pipe *P* at the train valve *V*, which is situated underneath the car, passing thence through the pipe *P'* to a point near the top of the heater *S*, where it receives a special T fitting that makes connections with two steam valves *v*, each of which controls one of the $\frac{3}{4}$-inch pipe coils already mentioned as being inside the 2-inch coils *A*, *A'*. From the upper side of the T pieces *t*, *t* run the hot-water risers *R* and *R'*. These risers enter the expansion drum *D*. Hot-water outflow pipes *p* and *p'* run from the expansion drum *D*. These pipes *p*, *p'*, one to each coil, take a course right around the car, as shown by the arrows, coming back to the bottom of the coils in the heater *S*, the connection being made with the 2-inch

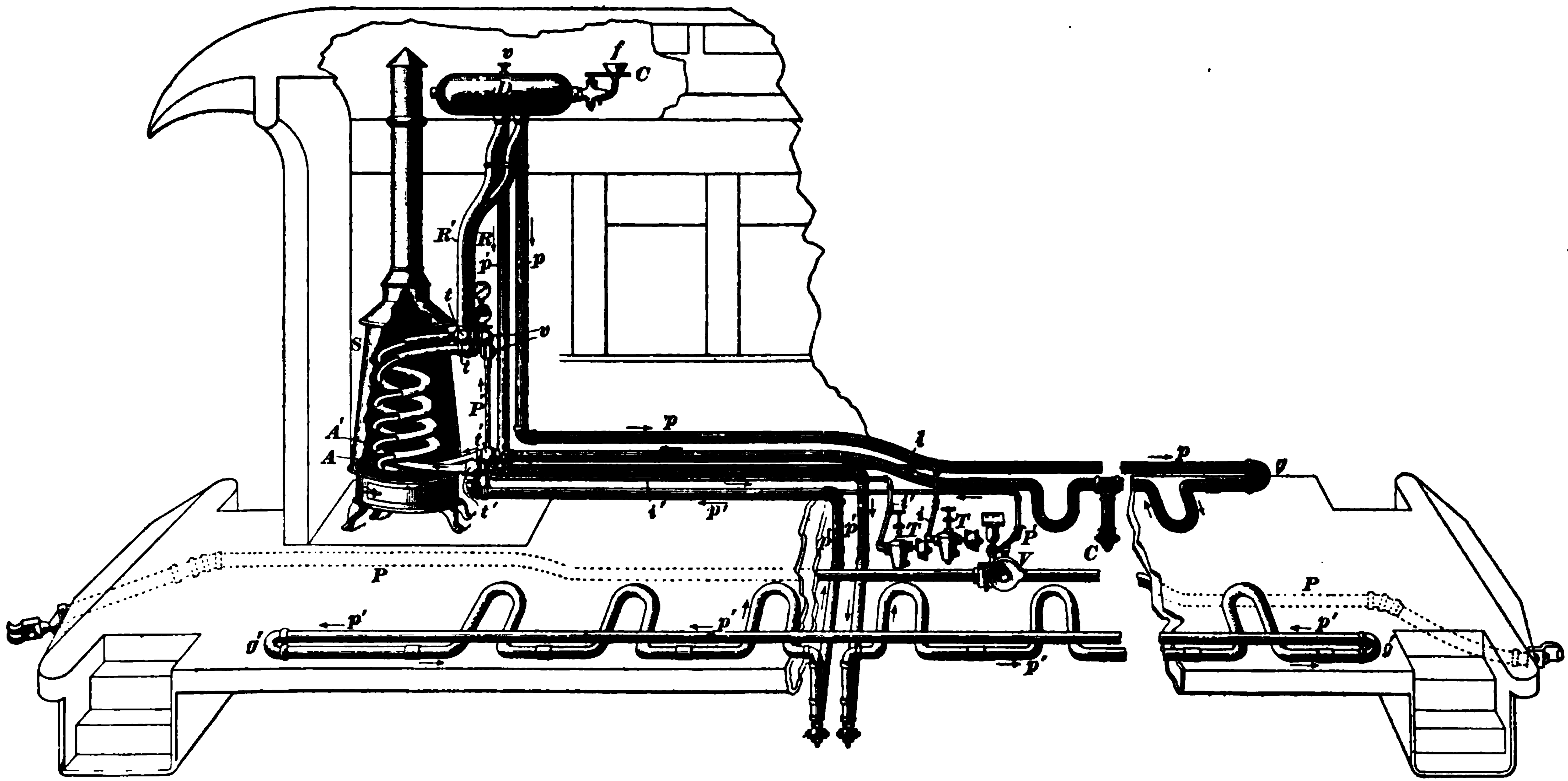


FIG. 15.

pipes by means of the T pieces t', t'; v, on top of drum, is the safety vent to relieve excessive pressures.

47. Action of the Apparatus.—Water is contained in the coils between the inner and the outer pipes, and is heated by steam passing from the train pipe P through valve V into pipe P', and so to the inner coils. Steam circulates through the two small coils and passes out at the bottom into the drip pipes i and i', and thence along to the steam traps T, T underneath the car; from these traps is drained off all the condensation that comes to them from the two inner coils.

It will be seen that this system of piping provides the power of two Baker heaters with only one stove and one expansion drum, and also that each side of the car can be controlled independently of the other. In this manner the heat can be very satisfactorily regulated, as in mild weather only one side of the car need be heated, while in severe weather the double circulation can be called into service and both sides heated up.

When the pipes in the heater S are filled, the water, as before remarked, fills the space between the inner and outer coils of pipe; therefore, when fire is used in the stove, the water is heated by the fire coming in contact with the outer pipes of the coil, and it will circulate in the way already described, with the additional advantage gained from the use of the sealed jet. When steam is used the water is heated by the steam contained in the small inner pipes—the $\frac{3}{4}$-inch coil.

OPERATING THE SYSTEM.

48. Working the Train-Pipe Valve.—In order to pass steam through the train pipe, from car to car, the train-pipe valve must be opened. When desired to shut off steam from the rear cars, the groove z must point to the word "shut" that is nearest the rear of the train. As already stated, when operating this valve, turn it as far as it will go, but without undue forcing.

49. Heating a Cold Train.—To heat a train, pass a high pressure through the entire train until steam blows out at the

rear; then close the rear train-pipe valve and open the globe valve at the heater. When working this globe valve, remember to always open it wide and close it tight, respectively. The pressure gauge at the stove should show from 10 to 40 pounds of steam, according to requirements as dictated by the weather. Whenever steam is being used in a car, hot water should escape from the steam trap under that car. If it appears that the trap does not let the water out freely enough, open the blow-off valve inside the car by turning the handle w', Fig. 13, or w, Fig. 14, just sufficient to let the water escape freely without blowing steam. By doing this, dry, hot steam can be retained in the pipes and increase the heating power of the coils in the heater.

Either fire or steam can be used in connection with this system, or both used together. If, in severe weather, steam must be turned off for more than about an hour, a small fire should be built in the heater so as to prevent the water freezing.

When using a fire in the heater, care should be taken not to choke it up with too much coal. The stove should never be more than half full; if filled up more than this, the heating will be retarded instead of helped.

The pipes should be filled with a strong solution of salt water, this having been found to be best for the purpose. Each side should be filled separately. Instructions for preparing the brine and filling the system have already been given.

CAR EQUIPMENT: HOT WATER.

(SYSTEM 2.)

50. Description.—Another method of hot-water heating sometimes used is illustrated in Fig. 16. It is very similar to the circulating system already illustrated in Fig. 15, differing therefrom principally in having only a single supply valve and trap, but having two expansion drums instead of one. Other differences in the equipment will be evident from the figure.

In this system, also, P is the train pipe and V the train-pipe valve, whence the steam passes through P' until it reaches valve v. There is in this case, as just remarked, only one valve V and also only one valve v, instead of two, as in Fig. 15. When

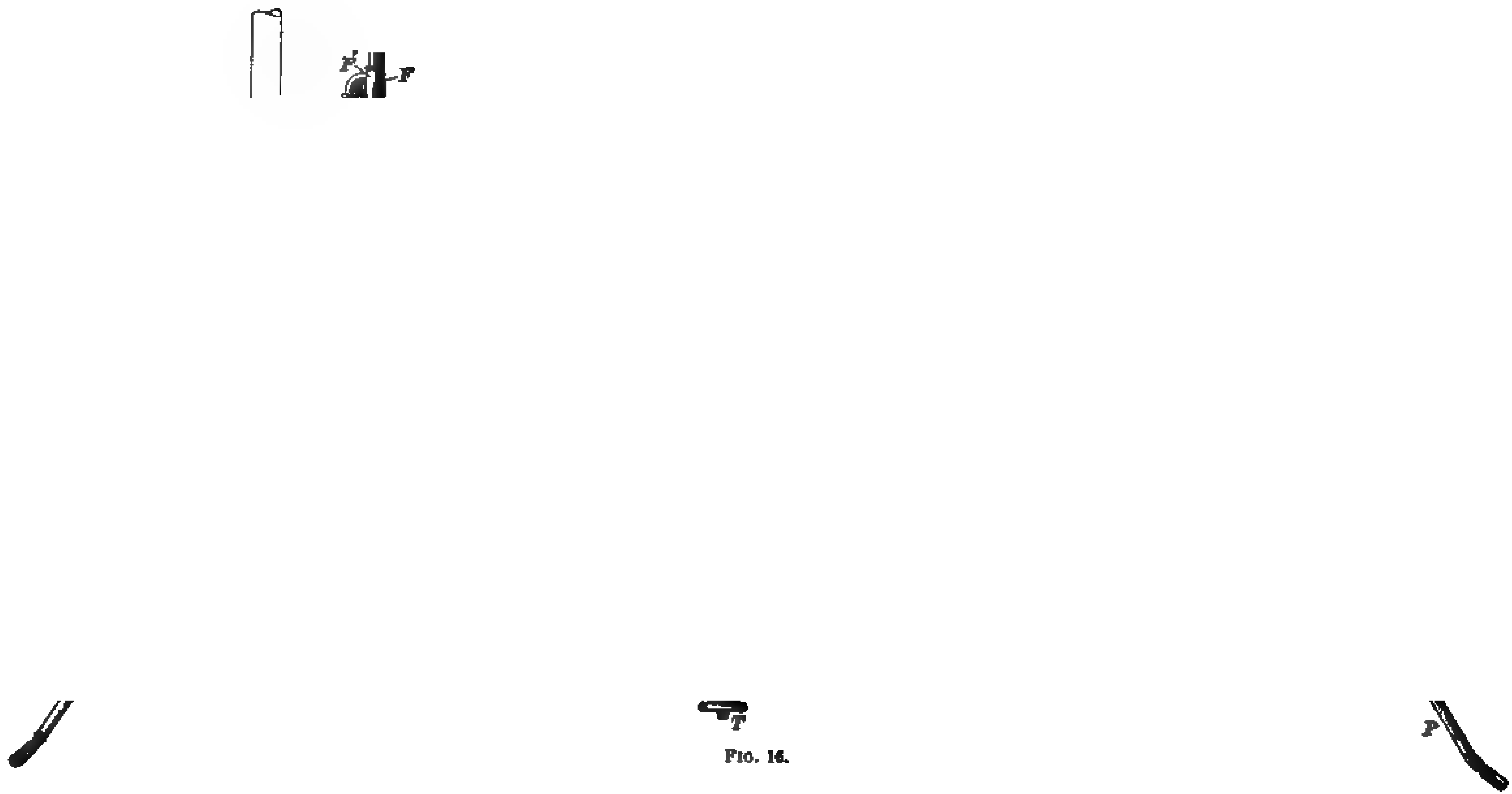


Fig. 16.

the valve v is opened, steam passes into both the inner coils in the heater S, through the two pipes a, a'. The water is heated in both coils simultaneously, and the condensation goes down the pipes d, d' and is carried off through the pipe i to the trap T. The risers R, R' pass up to the sealed jets F, F', as in Fig. 15, but each pipe goes to its own expansion drum in this case, instead of both going to the one drum. From the sealed jets run the pipes p and p'. In the illustration, the car is supposed to be broken in two places, and the end portions brought close together, thus enabling us to show the apparatus on a larger scale than we otherwise could in this space. The course of the hot-water pipe p is readily traced; it runs to the end of the car and makes the return bends shown, and then comes back to its **T** piece t', by which it enters the 2-inch coil at the bottom of the heater. The pipe p' takes the course shown, turns downwards to the crossover b, and passes to the other side of the car, returning thence through the other crossover b', as shown by arrows, and so to its **T** piece and into the bottom of the other 2-inch coil.

When fire is used in the heater, the outer surface of the large coils is in contact with it and so these are heated up, the result being the same as when using steam.

CAR EQUIPMENT: STEAM STORAGE.

51. Description.—The **direct-steam, terra-cotta, storage-heater equipment** is illustrated in Fig. 17. It will be seen that the pipes are arranged practically the same as in Fig. 10, except that after the lengths a, a', leading from the train-pipe valve V, have passed the steam valves v, v', they couple into a loop, as shown, from which loop the pipes p branch off on one side of the car and p' on the other. These pipes run into the storage heaters S, S', of which there are four in a car. This storage heater is an iron pipe, usually a 5-inch iron tube, inside of which are terra-cotta bricks; these are about 12 inches long, and are a snug fit. The two lengths of pipe p are not continuous as in Fig. 10; instead, the upper length stops short at the far end of the heater, as shown in view (b), which

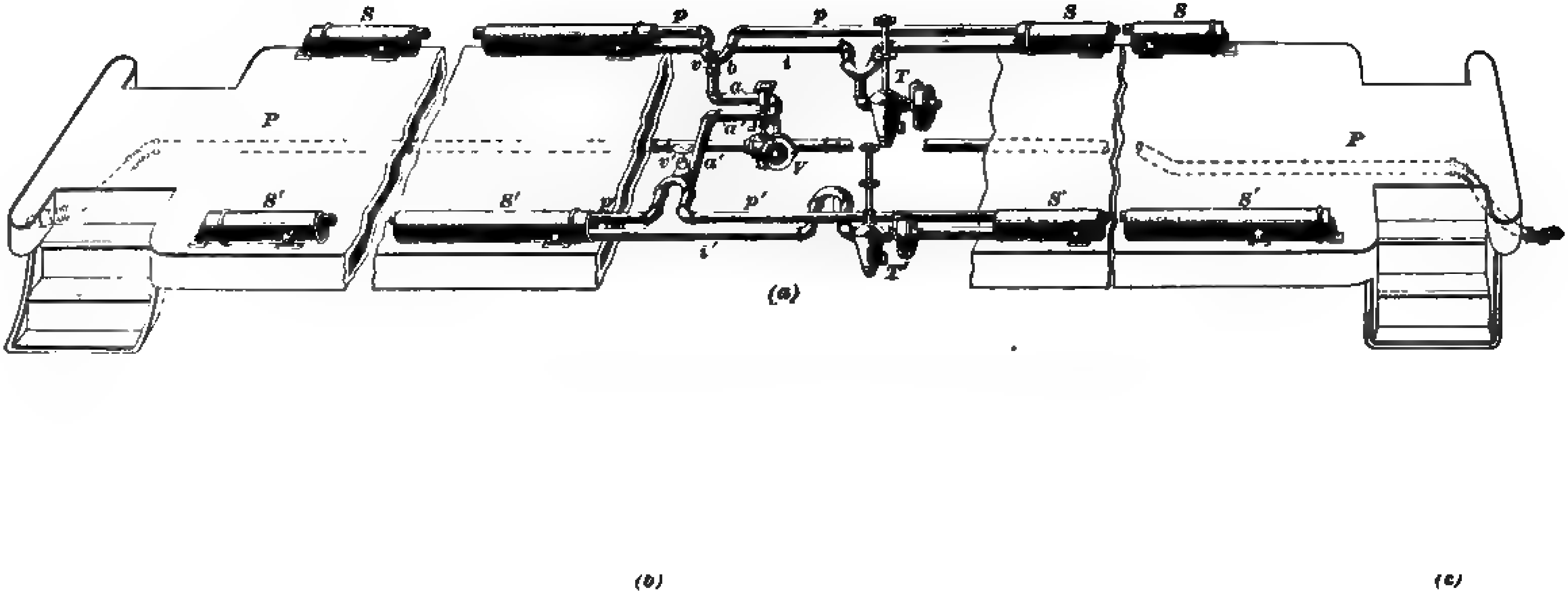


Fig. 17.

is a section of one of the heaters drawn on a larger scale. The tube or pipe *S* is shown in section in the left-hand portion of (*b*), the bricks *b* being shown in position, together with pipe *p*, the whole being supported on the stands *s*. View (*c*) is a cross-section of the heater showing the grooves *g* in the bricks *b*. The heaters are set with a fall toward the center of the car, as shown, so that any condensation may the more readily draw down to the end *e* and so out of pipe *i* into the trap *T*, which is of the same design as that in Fig. 10. These heaters are placed close up to the truss planks, shields being provided between the seats, as in the other heating systems already illustrated.

52. Action.—Steam passes from the train pipe through the pipe *a*, past the valve *v*, and thence through pipes *p*, *p* to each of the heaters on that particular side of the car. It passes out of the pipe *p* into the heater and then returns through the grooves or corrugations *g*, passing out of the heater by pipe *i*, and so on to the trap *T*. In its passage through the heater its heat is absorbed by the bricks, which have the property of taking up quite a considerable quantity of heat; this heat is then given out and diffused throughout the car.

THE SAFETY COMPANY'S SYSTEMS.

53. As is the case with the Gold Company, the Safety Company uses several different arrangements, or systems, which will be described in turn. In each one the main scheme is the same, the steam supply being taken from the locomotive and passed along a train pipe running underneath the cars the whole length of the train, a train-pipe valve under each car allowing the steam supply for that car to be taken from the main pipe.

ENGINE EQUIPMENT.

54. Fig. 18 shows the arrangement of the engine equipment. Steam is taken through a dry pipe *p* in the interior of the dome, as shown, the pipe opening into the highest point of the dome and leaving the back head of the boiler at

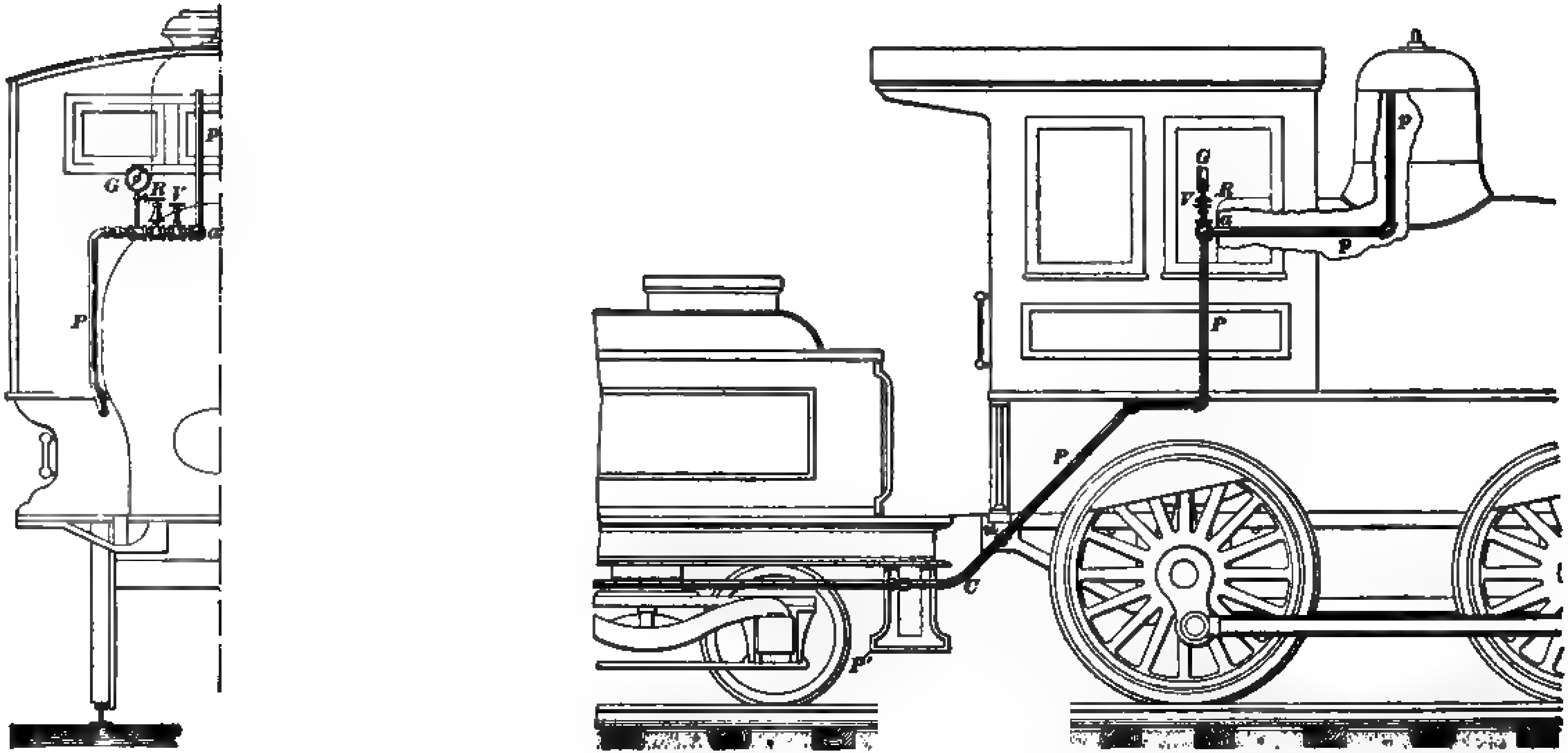


FIG. 12.

the point a. The valve V controls the steam supply from the boiler. R is the pressure regulator which regulates the pressure to the train. A pressure gauge G is connected with the side of the regulator, and thus indicates the steam pressure on the train. The pipe P runs to the rear end of the engine, where it receives the union u. Connection is made here with the steam coupler C, which in turn connects with the pipe P' that runs to the rear of the tender and is fitted with a steam hose C'. Its rear end is 12 inches from the center line of tender and 33 inches above top of rail.

STOP-VALVE.

55. The stop-valve included in the engine equipment supplied by the Safety Car-Heating Company is illustrated in Fig. 19, which shows the valve in section; it is not essentially different from the one shown in Fig. 7, except that in the present case the bonnet H is secured to the body of the valve by the screws I, whereas in Fig. 7 it is screwed into the body by means of the hexagon H. In the present figure, the reference letters are the same as those used for the corresponding parts in Fig. 7.

FIG. 19.

PRESSURE REGULATOR.

56. Description.—In connection with trains heated on the above system, the locomotive is supplied with a Mason reducing valve for the purpose of reducing and regulating the pressure of steam supplied to the train. A section of this valve is shown in Fig 20. Steam from the boiler enters at A and passes out at B into the train system, the connections being made by the unions shown. The steam passes into B' through the main valve C when the latter is raised by piston D moving upwards. Piston D is moved upwards by the steam that comes through port p' when the auxiliary valve c is moved down

(that is, opened) by the force of spring F, this valve c remaining open as long as the pressure in B' is below a certain amount. The port p' passes around behind chamber A.

57. Action.—When steam first enters at A, it finds the auxiliary valve c open, as just explained, and so passes by that

Fig. 20.

valve and goes up port p and down port p' into the space underneath piston D. We now have boiler pressure acting on

main valve C and also on piston D; the latter having twice the area of C, it rises and forces C open against resistance of spring H, thus letting steam pass into B' and on into the train system. The steam in B' also passes up port q and acts on diaphragm G. When the pressure in the train, and therefore in B', has reached the desired amount, diaphragm G is forced up against the resistance of spring F, thus allowing the steam in A' to close the auxiliary valve c and thereby shut off the steam from ports p and p'. Boiler pressure is thus shut off from underneath piston D, but still acts on top of valve C, which it therefore closes, and in doing so shuts off live steam from the train system. When valve C closes, it forces piston D downwards; the steam that is trapped in beneath this piston exhausts through port r and passes on into the train system, the piston being made a loose fit to allow of this. This piston is provided with the dashpot E so as to prevent chattering or pounding when the pressure is suddenly reduced. The springs H and f assist in making the action of valves C and c more prompt, tending always to keep these valves on their seats.

58. Using the Regulator.—The regulator is opened by turning the wheel handle J in the same direction as if one were unscrewing a nut—namely, from left to right. This wheel may be held in any one of twelve positions by the pin P, which drops into one of twelve recesses in the plate L, being forced into the recess by the spring S, which latter is held in position by the small screws shown. Time must be allowed for the train system to fill up to the required pressure.

If the regulator will not maintain a low pressure, it is probably due to a leaky valve C or to dirt on the seat of the valve. When about to take the regulator apart, relieve the tension on the diaphragm spring F by screwing the wheel handle around in the same direction as when tightening up an ordinary nut. Then unscrew the spring case I and remove the button b, diaphragm G, and cap K containing the auxiliary valve c. Pull valve c out, clean its seat, and also make sure that its stem works freely up and down in hole h. Next, insert a screwed

rod (supplied for the purpose) down through the hole *h* into the tapped hole in piston *D* and see if the latter works freely. Note that *D* cannot be raised and lowered very suddenly, on account of the resistance of dashpot *E*. If piston *D* is found to be stuck fast, remove the dashpot *E*, pull out the piston and clean it carefully with fine emery cloth, wiping it quite clean before replacing. Having made sure that the auxiliary valve *c* has a good bearing on its seat, and also that its stem moves freely in its hole, replace cap *K* with valve *c* therein. Before putting on the spring case *I*, see that the diaphragm is clean and that there is no dirt between it and the spring case or the body *M*.

HOSE COUPLERS.

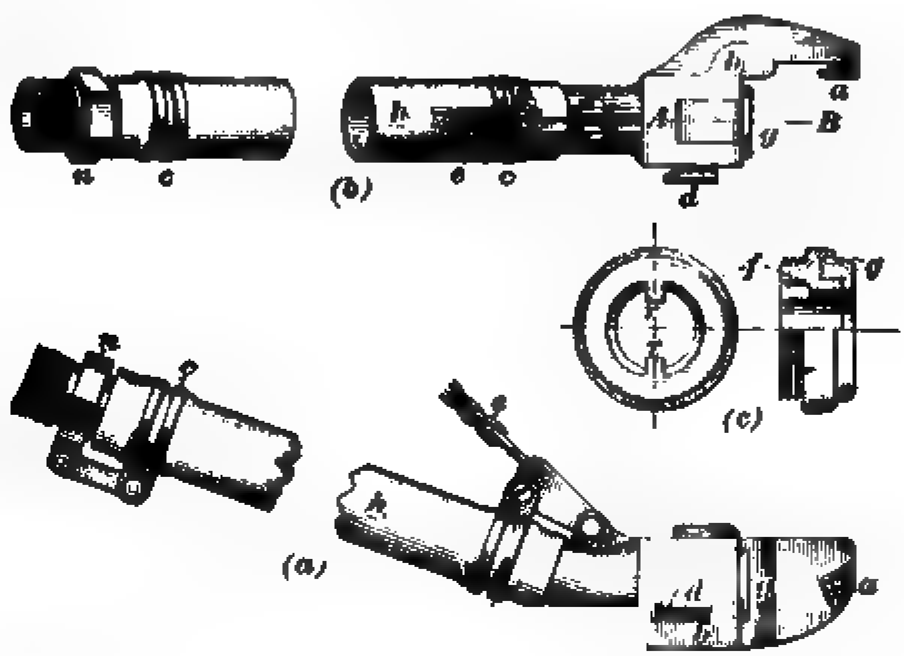
59. Straight-Port Coupler.—The hose coupler shown in Fig. 21 is now the standard straight-port coupler used by the Safety Company in their heating systems. In Fig. 21, (*a*) shows a side view of the coupler, while (*b*) represents the coupler as seen from above. In these views, *b* is the coupler body; *h*, the steam hose; *c*, the hose collar or band; *n*, the hose nipple; and *g*, the gasket, which, coming in contact with a similar gasket in the adjacent coupler on the next car, makes the coupler joint steam-tight.

This gasket *g* and its case *f* are shown separately at (*c*), the left-hand view representing the device as seen from the back, and the right-hand illustration showing a side view of it, the upper half being in section, to show how *g*, the gasket proper, is held inside its case *f*. There are two ribs *r* inside the case *f*, their purpose being to assist in screwing the device in or out of place in the coupler body *B*. Any flat bar of iron that will enter the case will answer for this operation.

The lipped projections, or lugs, *a* and *d* on the coupler body are for locking the pair of couplers together, *a* on the one coupler engaging with *d* on the other. The dotted lines in (*a*) show the outline of the inner surfaces of these lugs.

The Safety Company have lately made a modification in their straight-port coupler, the new design being shown in (*d*). The

left-hand illustration represents the coupler cut in two to show the gasket in place; the other illustration shows the coupler as seen endwise. The end of the coupler is recessed out squarely at *h* to take the gasket, while at *i* it is cut under, forming a recess into which the split ring *r* is sprung. This recess being formed slanting, so to speak, prevents the ring from coming out when sprung open in place, and it thus serves



(a)

FIG. 21.

to keep the gasket in position when the coupler is not in use. This ring is very readily removed when required to withdraw the gasket.

A tail-coupler has lately been devised that is intended for use on the rear of the last car. By the use of this device all the train-pipe cocks may be left open and the condensed water allowed to flow into and drip from the rear coupler through an angle valve attached to the tail-coupler.

CAR EQUIPMENT: DIRECT STEAM.

(SYSTEM 1.)

GENERAL DESCRIPTION.

60. In dealing with the various car equipments, we will take the **direct-steam** system first. What the Safety Company term their standard system, however, is a hot-water one. The arrangement of the piping varies somewhat on the various cars—ordinary passenger, parlor, baggage, express, mail, etc.

FIG. 22

Fig. 22 shows the arrangement of the piping on a passenger coach, together with the necessary valves, cocks, etc., being a plan view of the car. In these views, which are all lettered to correspond with one another, P is the train pipe, which, at mid-length of car, branches into the two cross-pipes P' and P''. These cross-pipes rise up through the floor, underneath two of the seats, and receive the steam-inlet valves v and v', by means of which the amount of steam allowed to enter the heating pipes in the car is controlled. V and V' are the train-pipe cocks, fulfilling the same duty as the train-pipe valve in the Gold systems; they are provided with sockets and floor plates. Now, suppose this car is the last one in the train, and that the end marked

R is the rear end, then the train-pipe cock *V'* must be closed and all other cocks left open. If the other end of car, marked *F*, is the rear end, the cock marked *V* will have to be shut, and the others left open. Suppose, again, that the ends of the car are as now marked—*F* for front and *R* for rear—and that it is not the rear car of the train; in that case, if we shut off steam to this car by closing cock *V*, we of course shut off steam from all cars behind it. If, however, we want to shut off steam from this car, but not from those behind it, we leave *V* and *V'* open and close valve *v* or *v'*, according to which side of the car is required to be cut out. The cocks *V* and *V'* are provided with sockets.

After steam leaves valve *v* it passes into the upper steam pipe *p* and then to the end of the car, around the bend *g*, and returns along lower length of *p* to the center of the car's length, at which point the two lengths of the lower pipe *p* approach each other and turn inwards, forming the loop *L*. This loop ends in a **T** piece *h* having a side outlet to which is fitted a drip or drain valve *u*.

The lengths of piping *p*, *p* on one side of the car and *p'*, *p'* on the other constitute the heating surface, which, by radiating out its heat, warms the car, the amount of radiating surface being proportioned to the size of the car.

The train pipe *P* is set so as to drain from the center to each end of the car. Also, the upper length of the heating pipe *p* falls from the center of the car to each end, while the lower length falls from each end to the center, so that all condensation drains to the loop *L* and so to the drip valve *u*.

TRAIN-PIPE COCK.

61. In the Gold systems of car heating, the supply of steam from the train pipe to the cars is regulated by means of what is called the train-pipe valve, the one valve serving to shut off the steam whichever direction it may be coming in. In the Safety Company's systems this same duty is performed by the **train-pipe cock,** one of these cocks being placed on either side of the point where the pipes branch off to the cars

(see Fig. 22), wherein v and v' are the cocks from whence run the supply pipes to the sides of the car. This train-pipe cock is of the ordinary plug type, asbestos-packed.

OPERATING THE SYSTEM.

62. Heating a Cold Train.—First of all see that all the steam hose are coupled up, and then open wide all the train-pipe cocks. Turn on steam and blow out all the condensation from the train pipe. Then shut the rear cock on the train, to prevent further steam from escaping.

Regulate the heat by means of the valves v, v'. The temperature of steam increases with the pressure; the higher the pressure, therefore, in the radiating pipes, the higher will be the temperature. The volume and pressure of steam admitted to the pipes are controlled by the valves v, v' under the seats. The wider the valve v (or v') is opened, the greater the volume of steam admitted to the pipe p (or p') on that side of the car. This inlet valve and the drip or drain valve are close together. The inlet valve is the larger one of the two; it is also distinguishable from the other by having the words "inlet valve" on its wheel handle.

63. Care of System.—The drip valves must be adjusted so that water, but not steam, escapes through them. When the train is about to be laid up, the rear train-pipe cock ought to be opened before cutting off the engine, so that all condensation will be blown out of the pipes; it is desirable to open this cock before reaching the last station of the run. All valves must be left wide open and all the hose uncoupled.

At the beginning of the cold season, it is a good plan to clean out the pipes well. This may be done by flushing them with water, or by blowing steam through them under considerable pressure, at the same time tapping the pipes to remove any scale therein. While the pipes are being blown out, the drip valves u and u' should be left wide open.

CAR EQUIPMENT: DIRECT STEAM.

(SYSTEM 2.)

GENERAL DESCRIPTION.

64. Arrangement of Piping, Etc.—Fig. 23 illustrates another system of direct heating that is sometimes installed by the Safety Company. In this system the drain valves *u* and *u'*, of Fig. 22, are replaced by the automatic traps *T* and *T'*, while the train-pipe cocks *v*, *v'*, placed in the center of the car, are omitted. The end train-pipe valves *V* are used instead, and are located one at each end of the car, under the platforms. Each of these valves is fitted with an extension handle that can be reached through a hole in the riser *r* of the platform view (*d*).

In the figure, (*a*) is a plan view of the car floor and piping; (*b*) is a side view showing the car in section; (*c*) is a cross-section of the car on the lines *A*, *A*; and (*d*) is an end view showing the location of the end train-pipe valve. Those parts of the apparatus here referred to that occur also in Fig. 22 are marked with corresponding letters. The course of the steam is much the same as before; it is taken from the train pipe *P*, passes through pipes *P'*, *P''* to either side of the car, the pipes after rising through the floor receiving the supply valves *v*, *v'*. After completing the circuit of the car, the two halves of the lower length of radiating piping come together, forming the loop *L*; from this loop a short pipe *j* leads down to the trap *T*, from whence the condensation escapes, instead of by the drain valve *u* used in Fig. 22. However, a blow-off valve *u* is attached to the high (the non-outlet) end of the trap; this valve provides for a quick discharge, if required. In most equipments—particularly for cold climates—these valves are furnished with extension handles reaching from the valve wheel to the car floor. They can thereby be operated from inside the cars. This is found to be very convenient; for both when desiring to heat up a car quickly and also to drain the pipes quickly when steam if shut off, it is found an advantage to open this valve,

(d)

Fig. 24.

which, by the way, is identical with that used as a drain valve in Fig. 22. The trap *T* is set with a fall of two inches, its outlet end being lowest. When steam has been turned into the car for testing, the trap may be adjusted, slacking back the lock-nut at the outlet end of the trap and then screwing the shank upwards. Do this until steam escapes freely and then close it again until nothing but water escapes. Then screw up the nut tight, taking care that the shank does not shift during the operation. After the trap has been thus adjusted, it will work automatically.

By the use of trap *T* the removal of the condensed water is rendered automatic and independent of any attention from the trainmen.

OPERATING THE SYSTEM.

65. Heating a Cold Train.—First, couple up all the steam hose and then open wide all the train-pipe valves. Turn on steam and blow out all condensation from the train pipe. The amount of steam generally should not exceed 40 pounds in the case of a train containing eight or fewer cars; if the train is longer than this, allow 5 pounds extra for each additional car. When the train pipe is well blown out, shut the rear train-pipe valve. As remarked in a previous article, there is a small groove in the seat of each of the train-pipe valves; therefore, there will always be a slight escape of steam from this rear valve when closed, as long as the car is in service.

As regards regulating the heat, the same instructions apply here as were previously given. In addition to the instructions then given concerning the adjustment of the temperatures, something was said about preparations for disconnecting the engine and laying up the train, all of which applies equally in this case.

66. Care of Equipment.—As regards the drip traps, see that they discharge only hot water—not steam. If they are not doing this properly, adjust them correctly. The remarks previously made about blowing out the pipe apply to this system also. While that process is being carried on, the blow-off valve

u on the end of trap *T* should be opened wide. If there is no such valve on the trap, the trap itself should be opened wide and then be readjusted afterwards.

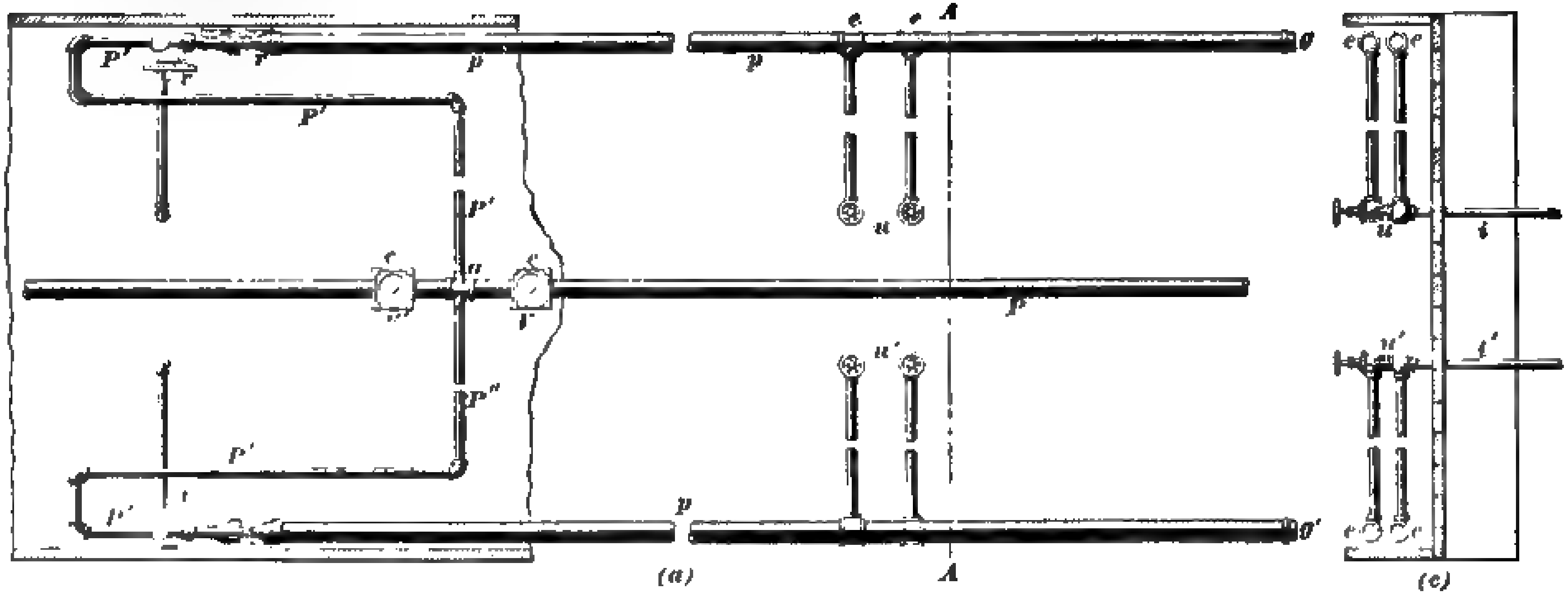
CAR EQUIPMENT: DIRECT STEAM.

(Regulating System.)

GENERAL DESCRIPTION.

67. Main Scheme.—One of the drawbacks to using the direct steam system is the liability to overheat the car; the heat of the radiating pipes being then much greater than when hot water is used. This being so, it would be an advantage to be able to vary and control the total heat given out by the pipes. As ordinarily done, this is not very satisfactory, for the usual procedure is to throttle the steam and reduce the pressure. Now, the degree of regulation thereby obtained is not considerable, for the range of temperature corresponding to the reduction of pressure that is practicable is not great compared to the whole temperature. Obviously, a desirable arrangement would be one wherein we could decrease the actual amount of heating surface used, and to decrease it by appreciable amounts. This is what the Safety Company achieve in this system (Fig. 24), and, as will be seen, they can at pleasure cut out one-quarter, one-half, or three-quarters, or the whole of the heating surface that warms the car.

68. Arrangement of Piping, Etc.—In this system, as also in that illustrated in Fig. 22, the radiating pipes that constitute the heating surface consist of pipes on each side of the car, placed vertically one above the other; but in this case they are actually separate pipes, whereas in Fig. 22 the pipes are one continuous length bent round at the two ends so that the upper and lower lengths of piping form one continuous pipe. In the present case, however, steam can be in either the upper or the lower length without being in the other, for, as will be noticed, each length is closed at its far end with



No Steam

Steam on Lower Pipe

(a)
Steam on Both Pipes

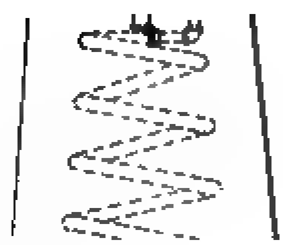
FIG. 24.

a cap g or g', and so is rendered separate from its neighbor. Another point of difference is that the steam comes in at the end of the car, instead of at the middle, as in Fig. 23.

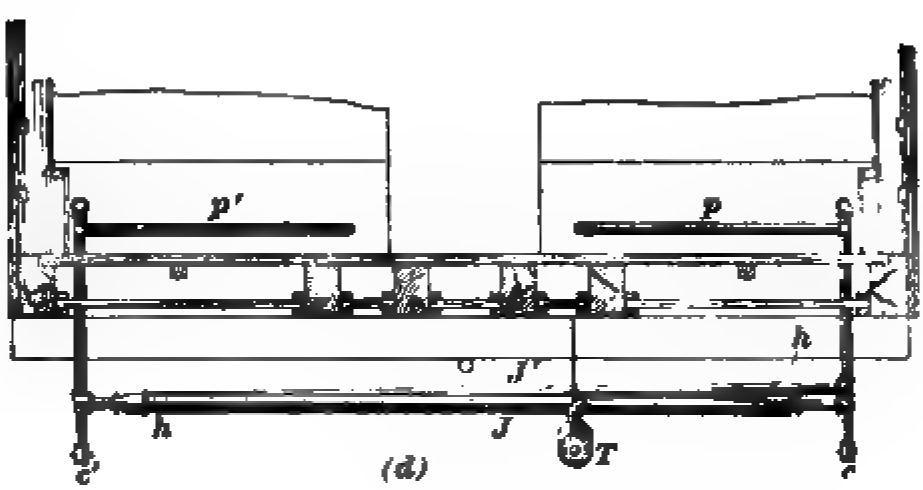
Referring to the present figure, P is the train pipe, in which are the two train-pipe cocks V and V' that serve to shut off the steam from the cars in rear of the one under consideration. In between these cocks is the small piece a from whence branch the cross-pipes P', P'' leading one to each side of the car. In Fig. 22 the steam supply to the car is controlled by the angle valves v, v'. In the present case this duty is performed by the distributing or regulating cocks v, v situated at one end of the car. From this cock v run the radiating pipes p along the side of the car near the truss plank as before. These pipes have a slight fall away from the regulating cock v to near the far end g of the car. In each of these pipes, at about 4 feet from the end, is placed an eccentric T piece e. This T is located underneath a seat when practicable, and a 1-inch pipe leads from it to the drain valve u, from which runs the drip pipe i through the floor of the car. Where there are no cross-seats, these drain valves u, u' are placed up near the side of the car. Each of the radiating pipes is set with a fall from the regulating-cock end to the eccentric T piece e; it also has a fall backwards from its end g to this same T. Thus, these pipes run downwards toward the valve u from either end of the car.

69. Action and Advantages.—In (d), Fig. 24, is shown the regulating cock in three positions; the views are taken looking sideways at the apparatus when in position in the car; in fact, they correspond to view (b). The upper illustration of (d) shows the position of the cock handle when steam is shut off from both pipes. The middle one represents steam being admitted to the lower pipe only; while the bottom illustration shows steam going into both pipes.

This system is very convenient for cars running in suburban service, where the cars have to be heated up quickly for short runs. This can be readily done by heating all the pipes, and by a movement of the cock handle, which is a permanent fixture, the heating power can be reduced one half—the reduction



(c)



(d)

being uniform throughout the car, owing to the pipe that has been cut out extending the whole length and not occupying merely one particular section. So, also, whether one pipe be cut out, or three, there is still a practically uniform heating of the car, excepting such slight differences as may result from there being an excess of heating surface on one side.

OPERATING THE SYSTEM.

70. Heating a Cold Train.—See that all the steam hose are coupled up, and then open wide all the train-pipe cocks. Turn on the steam and blow out all condensation from the train pipes. Then shut the rear train-pipe cock, to prevent further escape of steam.

The heat is regulated by means of the valves in the radiating pipes. The valves are adjusted as explained in the last article, sufficient radiating surface being brought into play to give the required temperature.

71. Care of System.—The drainage of the radiating pipes is effected by means of the drip valves u and u' placed near the ends of the car. When steam is turned on, the drip valves on the lower pipes should be opened until steam escapes from them; the valves on the upper pipes need not be opened except in very cold weather. After steam escapes from the drip valves, they are to be closed.

CAR EQUIPMENT: HOT WATER.
(Single Circulation: Single Train Pipe.)

GENERAL DESCRIPTION.

72. Main Scheme.—In this system the fire in the Baker heater is dispensed with, its place as the heating agent being taken by steam drawn from the boiler of the locomotive. As in the Gold systems, the heater is left in such condition that at any time fire may be substituted for steam from the locomotive. Fig. 25 illustrates this system. Steam is taken from the train pipe P at the T piece t, and goes through the pipe P' to the

regulating valve *v*, whence it passes through *a* to the anti-hammering jacket *j*. It leaves this jacket by the pipe *b* and enters the high end *h* of the heating jacket *J*, passing out again at the lower end *b* and running along to the high end *n′* of the crossover jacket *J′*, which it in turn leaves by the pipe *b′* and enters the high end *n″* of the crossover jacket *J″*. It leaves the low end of this third jacket by the pipe *b″* and passes into the high end of the trap *T*. The action of this trap has already been described; it is fitted with a blow-off valve *u*, as before. All these heating jackets have an upward inclination in the direction of the circulation of the heated water, the steam thus flowing down them, so to speak, having a gradual fall from the time of entering the high end of jacket *J* until leaving the lower end of jacket *J″*. The water inside these jackets is heated by the steam passing through them, which materially aids the circulation and reduces very considerably the time taken to induce complete circulation of hot water throughout the system. This practice of applying the heat at several points in the system is of considerable benefit. The heat of the steam is, of course, not as great as would be that of fire in the heater, but whereas the latter is applied to only one portion of the circulating system, namely, the coil in the heater, the former is applied to three separate portions, the result being a more uniform heating and a higher average temperature in the pipes throughout the car. These three jackets, then, correspond to the inner coil of piping used in the heater of the Gold system, the duty in each case being to hold the steam that heats the water. This inner coil is not used in the present instance; but the ordinary Baker coil is connected at both ends with the circulating system, so as to be used with fire when required. Wherever the heating jackets or the steam pipes extend through the car floor, they are clothed with a suitable non-conducting covering. Arrows placed alongside the pipes *b*, *b′*, and *b″* show the path of the steam, that of the hot water being indicated by arrows placed on the pipes *p*, *p′* and on the heating jackets *J*, *J′*, *J″*. The temperature of the car is readily regulated by controlling the supply of steam from the train pipe, this being done by means of the angle valve *v*.

73. Piping and Fittings.—The series of hot-water pipes is arranged as follows: From the top of the pipe coil in the stove heater runs the hot-water riser *R* into the drum *D*. The heated water passes out of this drum through the pipe *p* and runs along the side of the car as far as the center, where it drops below the floor and runs into the jacket *J''*, passing therein to the other side, where it rises into the car again and goes through pipe *p'*, which runs along the side of the car to the end *A*. At this point it makes the turn *g'* and comes back along the floor, in a series of loops under the seats, to the other end *B*, where it again turns and comes back to the center of the car by the upper straight length of piping *p'*. Here it again drops below the floor and passes to the other side of the car through the crossover jacket *J'*; it then rises and goes through the straight upper length of piping *p* to the end *g* and returns by the looped pipe to the heater end of the car, where it drops below the floor and enters the jacket *J*, passing out of that into the bottom part of the heater coil in the stove at *d*. This system is a "closed" one, as were also the systems previously described, the same body of water circulating through the pipes over and over again, there being no exit for it. Hence, when it has once been filled with water to the proper level, no further attention is required. Draw-off cocks *c*, *c'* are placed in the location shown.

The supply of steam is drawn from the train pipe *P* at the fitting *t*, this being made the highest point in the pipe, so that water may drain from there down to each end of the car. Hitherto, the general practice of the Safety Company has been to use two train-pipe cocks in the center of the car, but their present practice is to use a train-pipe valve *V* at each end of the car, as here shown.

The purpose of the small jacket *j* placed up above the heater is to prevent **water hammer**, as the knocking noise in the pipe of a heating system is called, this being prevented by producing a pressure in the expansion drum as soon as steam is turned on, the pressure thus produced being proportionate to the steam pressure admitted at the system.

In order to discharge the condensation from the steam pipes,

and at the same time prevent the escape of uncondensed steam, the automatic steam trap already shown in Fig. 23 is used. It will be noted that in this case, it is not thought necessary to run an extension handle through the floor from the valve *u*, the object of this valve being merely to afford a means of blowing out the steam pipe occasionally or of getting rid of the condensation, if from any cause the trap should fail to work.

The Baker heater is used with this system, and is put up and kept in such shape as to be ready for use in the ordinary way (by fire) when emergency arises. After being put in place, the seal of the Baker heater pipes remains unbroken, and a fire may be started in the heater whether steam is in use or not, and without having to adjust any cocks, valves, or traps. The water always circulates in the same direction, whether fire and steam are used separately or together.

OPERATING THE SYSTEM.

74. Heating a Cold Train.—Couple up all the steam hose and open wide all the train-pipe valves or cocks. Turn steam on the system and let it blow right through the train pipe until it comes out at the rear end of the last car. Then close the rear valve to prevent steam escaping. Next open wide the valve *v* and adjust the trap *T*, so that practically only water escapes therefrom. When the car is warmed up sufficiently, regulate the heat by means of the valve *v*.

75. Care of System.—When the engine is to be disconnected from the train at the terminal, open wide the valve *V*, or the rear train cock, before reaching that station. Leave all valves wide open, the hose uncoupled, and a fire started in the heater.

As regards cleaning out the piping; this is not necessary if the system has been kept full of water all summer. If a hot-water system fails to circulate properly, and it is found that the water level is correct, a test may be made to ascertain whether or not the system is stopped at some point. To do this, draw off the water, connect live steam to one of the draw-off cocks, and

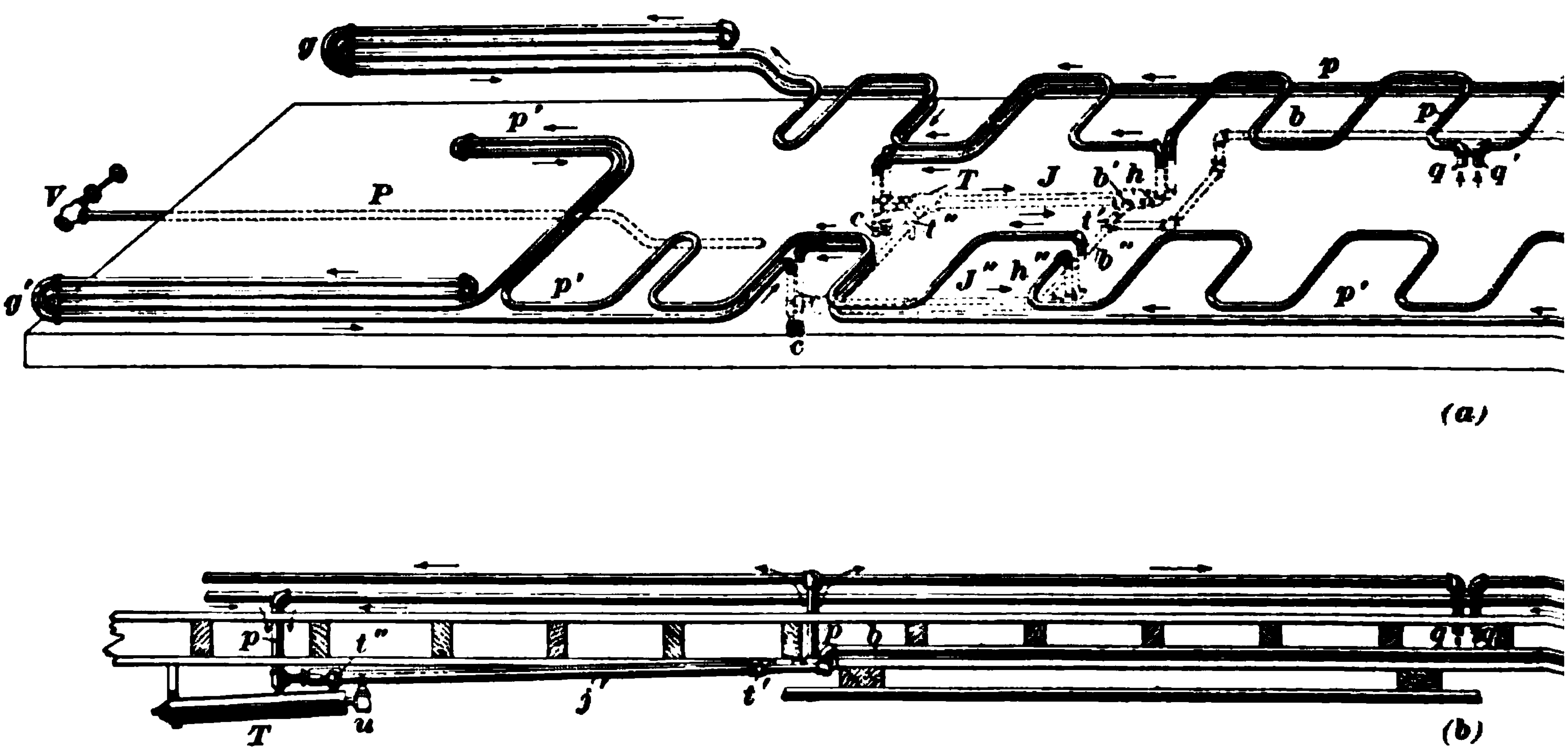


FIG. 26.

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then blow steam through the pipes, opening all the other draw-off cocks and noting whether steam comes out of them. As fast as each successive cock is found to blow steam, close it and pass on to the next one, proceeding thus until every foot of the circulating pipes has become hot, which will be a proof that there is no stoppage in the pipes.

CAR EQUIPMENT: HOT WATER.

(Double Circulation: Single Train Pipe.)

76. In Fig. 26 is illustrated a heating system that is especially suitable for sleeping and private cars and also for parlor, dining, café, and large postal cars. It is a **double-circulation** system, there being a separate set of piping on each side of the car. Inside the Baker heater is a double-coil generator, one of whose coils connects with the riser *R*, drum *D*, and piping *p*, and the other with *R'*, *D'*, and *p'*; thus, each side of the car has its own separate circulation. Each set of piping is heated in three places by jackets, the jacket *J* serving for both sets *p* and *p'*, while jacket *J'* is exclusively for piping *p*, and *J''* for piping *p'*. These jackets are so located as will aid most in the circulation, dividing the system into three parts, as already mentioned.

As seen from the illustration, end train-pipe valves are here used, steam being taken from the train pipe at the connection *t*, whence it passes through pipe *P'* and valve *v* to the anti-hammering jacket *j*. From this jacket two pipes *e*, *e'* lead to the two drums *D* and *D'*, and two pipes *f*, *f'* lead to the coils inside the Baker heater. From the lower end of the drum *j* runs the pipe *b* carrying steam to the three heating jackets. After leaving the first jacket *J*, the pipe *b* runs toward the center of the car, branching off at the T fitting *t'* into the pipes *b'* and *b''*, which lead to the jackets *J'* and *J''*. It leaves the other end of the trap by the pipes shown, and by means of another T fitting *t''* goes to the trap *T*.

The course of the radiating pipes may be readily traced in the illustration by aid of the arrows and letters marked thereon.

The piping p on its return to the heater dips down under the floor at q into the water tank, whence it rises again through q' and proceeds as shown. The water tank here mentioned is that used for storing water on parlor and sleeping cars. The heater pipes are run down through the floor and around the inside of the box that encloses this tank, with the object of preventing the water freezing in cold weather. Thus, the length of piping p is not broken at this point, but is continuous from q to q'; the pipes are shown broken here merely for convenience.

Each of the systems of piping p and p' is provided with three draw-off cocks c, as shown. Some of these cocks are placed under the low ends of the three heating jackets; the others are placed at the heater end of the car, where the piping crosses over; in doing this, the pipes dip down under the floor and form a vertical loop that has to be drained. An iron plate I or I' is fitted over the part of the floor where the pipes pass under.

THE CONSOLIDATED COMPANY'S SYSTEM.

77. A great number of cars, particularly in Canada and the West, have been fitted with the heating apparatus of the Consolidated Car Heating Company, whose systems embrace both direct steam and hot water. The general scheme of conveying and utilizing steam from the engine is virtually the same as in the systems already described, except that in one of those about to be described, the steam mixes directly with the circulating water.

ENGINE EQUIPMENT.

78. Fig. 27 shows the arrangement of the engine equipment, (a) being a side view, (b) an end view of the engine. Steam is taken from the boiler at the stop-valve V, passing thence by pipe p to pressure regulator R, which reduces its pressure down to the degree required in the train. From R steam passes through pipe P to the couplers between engine

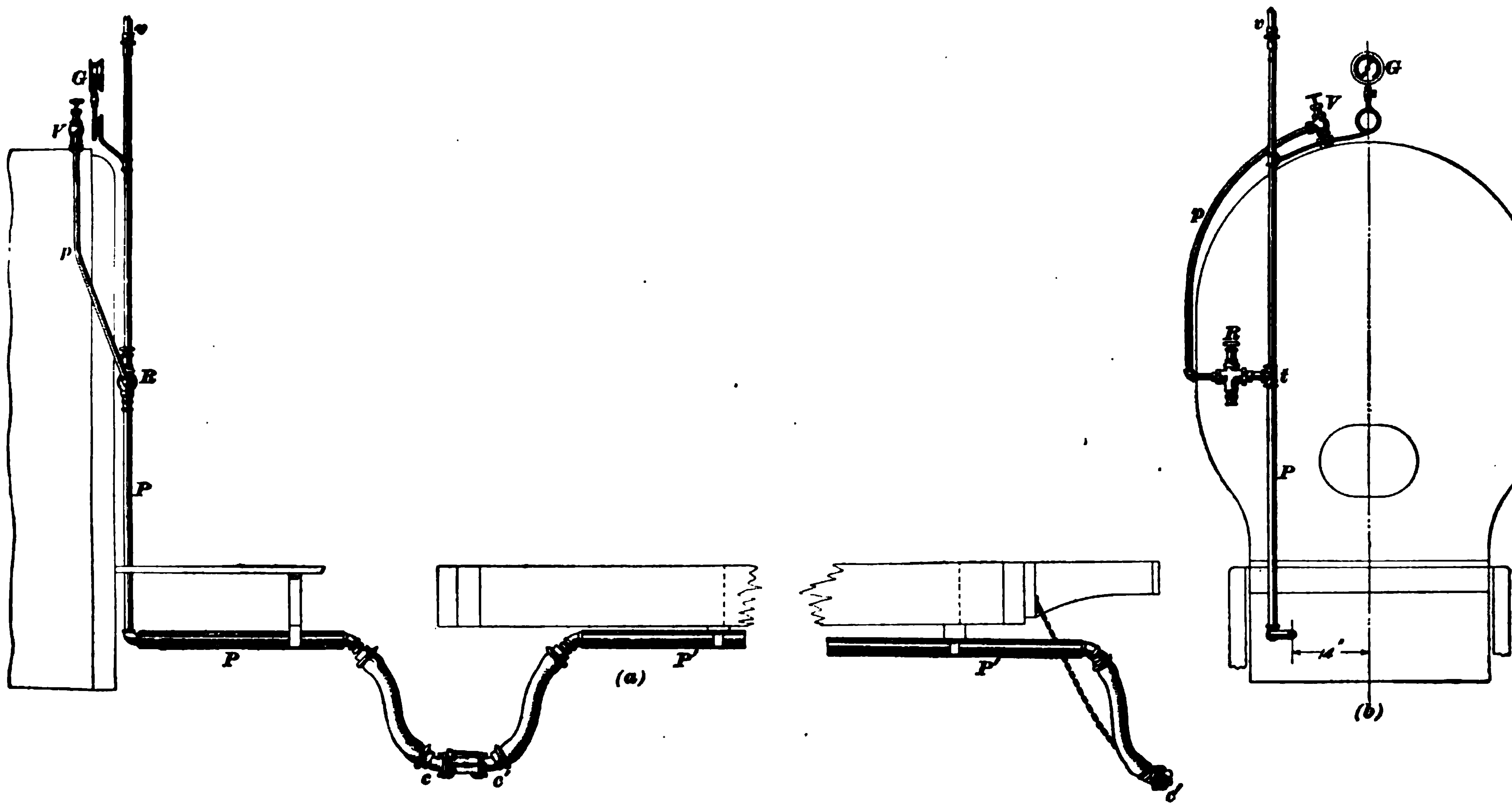


FIG. 27.

and tender, and thence along pipe P' to the train. The fitting t allows the steam to pass to the pressure gauge G and relief valve v. The coupler c at rear of engine is the Sewall lever coupler, the couplers c', c' at each end of the tender being standard Sewall couplers.

STOP-VALVE: PRESSURE REGULATOR.

79. The stop-valve used is a hard-seat valve of similar design to that shown in Fig. 7. Its construction permits it to be connected directly to the boiler, as in Fig. 27, or else placed horizontally at the side of the boiler; or it can be located in any suitable position in the steam pipe.

The pressure regulator is the same as shown in Fig. 20, namely, the Mason regulator.

RELIEF VALVE.

80. The relief valve v is shown in section in Fig. 28. It is used for the purpose of relieving the train pipe and also to warn the engineer if the pressure in the train becomes greater than intended. It is usually set at 50 pounds.

In the figure, a is the valve disk held down on its seat b by the spring c, the force of which is regulated by the setscrew d. The ring e screws up and down on a. The steam comes in through A, and passes between the arms f of the base and lifts the valve a; two openings, between a and b and e and b', through which the steam must pass, then present themselves. After steam has raised the valve a, it still encounters the last named passage and is thus held back, as it were. The wider this passage, the more easily will steam blow off; the opening it presents can be increased or decreased by screwing the ring e up or down, locking it in its new position by means of the setscrew g.

81. Regulation of Valve.—If the valve pops too suddenly and reduces the pressure too much, screw e further up on a so as to increase the opening between e and b'. If it

does not pop promptly, opening and closing too gradually, screw *e* down so as to approach nearer *b'*. It will be found, as a rule, that when the setscrew *d* is changed, the position of the ring *e* must be readjusted.

To increase the pressure at which the valve pops, screw down *d*; to lessen it, screw it up.

To take the valve apart unscrew the lock-screw *h*, remove the shield *i*, and entirely relieve the compression of the spiral spring *c* by slacking back the regulating screw *d*; after doing this, unscrew the casing off the base.

Before putting the valve in place blow out the pipe to which it connects, and use very little lead or grease in connecting it up, as it may get in the valve and impair its sensitiveness.

OPERATING THE ENGINE EQUIPMENT.

82. When the train is first made up, the engineer will, on receiving the signal for steam, slightly open the pressure regulator *R*, and then open wide the stop-valve *V* until *R* is receiving full boiler pressure. Next open valve *R* until gauge *G* shows the required pressure—25 to 50 pounds, according to the length of train and the state of weather.

FIG 28.

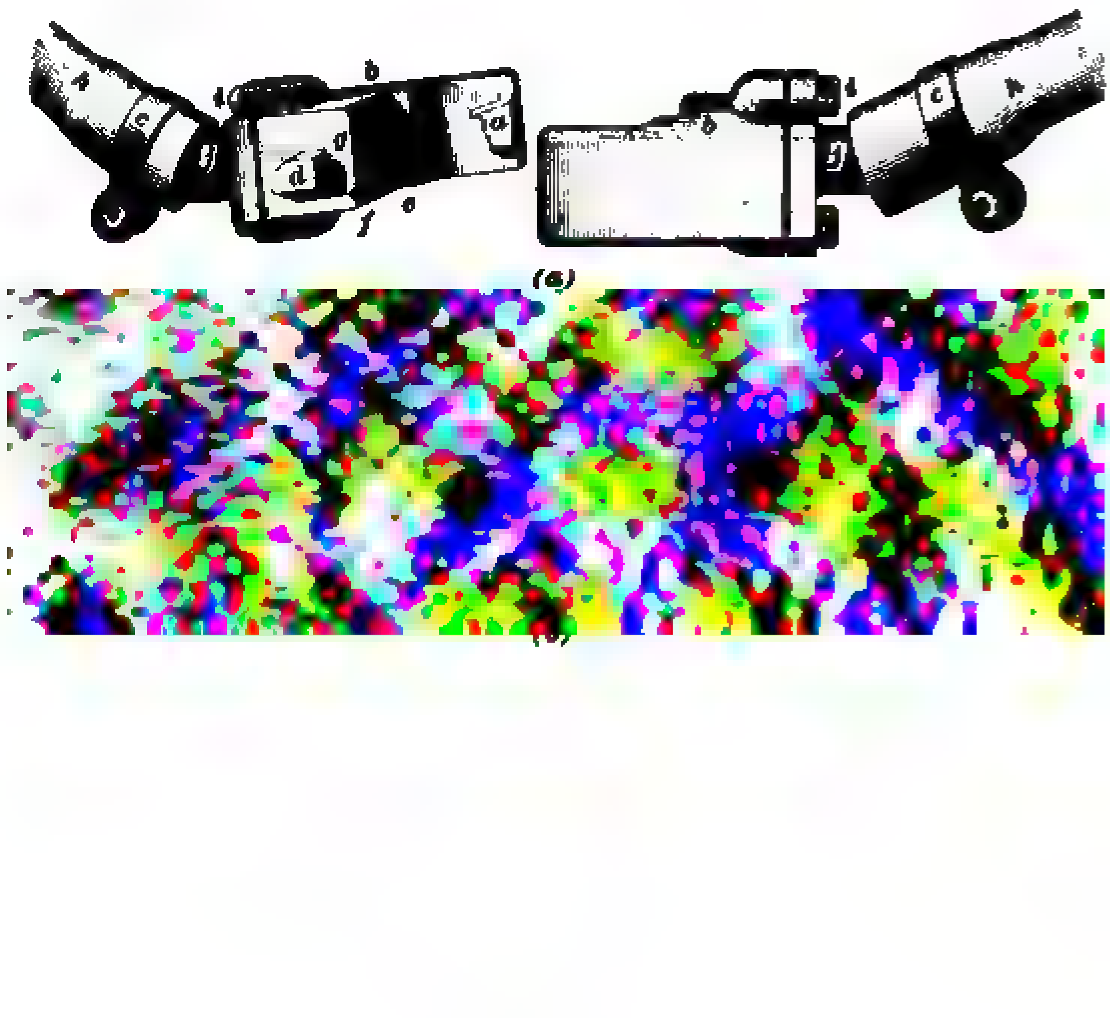
In shutting off steam, close valve *V*, but do not alter the regulator *R*; then, when next delivering steam to the train, only *V* has to be opened. The regulator *R* is to be altered only when steam is in the pipe and for the purpose of adjusting the pressure in the train; it is not to be used for admitting and shutting off steam to the train, this being done solely by the stop-valve *V*. This valve *V* should be closed about 3 minutes before entering stations that are terminal points or at which it is intended to cut off the engine or take on additional cars. Steam should not be shut off from the train while on the road without giving the trainmen notice.

HOSE COUPLERS.

83. The steam coupler used by the Consolidated Company is that known as the Sewall coupler. It is given in Fig. 29, view (*a*) showing the parts uncoupled, view (*b*) showing it coupled up, and view (*c*) showing a sectional view of it. *b* is the body and *c* is the collar holding the hose *h* in place on the nipple *j*. The two curved lugs *a* and *d* serve to lock the coupler together, forcing the gaskets *g* into contact with each other. On the inner face of each coupler are formed a lug, or tooth, *e* and a space *f*, the tooth in the one coupler engaging with the space in the other. These teeth act as a guide when coupling, and also subsequently keep the couplers in their right position relative to each other. The gasket *g* is gripped between the body *b* and the end *h* of nipple *j*, being tightened up by bolts *i* tapped into the body. If the gasket becomes at all worn, it can be forced outwards without removing it, by tightening up the nuts of bolts *i*. *k* is an air space surrounding the part of the nipple that would otherwise expose bare metal to the atmosphere; this prevents a great deal of the condensation that would otherwise take place. This coupler will couple with any straight-port coupler, and uncouples automatically. It presents a practically straight path to the steam.

The coupler used between engine and tender is the same as here shown, with the addition of a lever shown in Fig. 27.

This coupler, when connected with the adjacent one, can be locked in position by means of the lever, when they will not



(c)

FIG. 29.

uncouple until this lever is put back. It will couple with the ordinary coupler, the locking device not being brought into use unless desired.

CAR EQUIPMENT: DIRECT STEAM.

GENERAL DESCRIPTION.

84. Fig. 30 illustrates the method of piping used in the direct system of heating installed by the Consolidated Company. Steam in the train pipe *P* is controlled by train-pipe valves *V*. From *P* the steam passes to the sides of the car by the double crosspiece *c*, called the main steam casting, proceeding by pipe *P'* to the regulating, or controlling, valve *v*, whence

it goes through pipe *d* to the piping *p* that runs along the side of the car. After traversing the length of the car, the steam returns to the loop *L* and passes through the drain valve *u*, and thence through pipe *i* to the casting *c*, and out of the drip pipe *j* to the trap, when such is used. The whole arrangement is similar to that shown in Fig. 23, the reference letters used in these two instances and in Fig. 22 corresponding.

FIG. 25.

Another arrangement of piping is also used in which there are three pipes on each side of the car instead of two. The ordinary T piece *e* is replaced by a double center T connecting the two upper pipes, so that live steam passes from pipe *d* into these other two pipes. The return bend *g* is replaced by a three-pipe manifold, by which the steam that has just come through the two upper pipes *p* may return through the lower *p* to the center of the car, where a special return T replaces the loop *L*, a pipe leading to valve *u* as before.

The regulating valve *v* and the drain valve *u* are identical, except that the former has the larger wheel. The train-pipe valve *V* has an extension handle, accessible from the side of the car. In very cold climates a notch is cut

in the seat of this valve, so that there will be a constant slight discharge of steam and condensed water, preventing any freezing of the train pipe.

Fig. 31.

The casting *c* plays an important part, as it keeps the water of condensation from freezing in pipe *j*. The live steam from the engine passes through this casting in close proximity to the

drip pipe *j*; therefore, as long as there is steam in the train pipe, the drip cannot freeze.

Sometimes it is felt advisable to use a trap to look after the condensation, instead of having the drip valve *u*. When such is the case, the apparatus shown in Fig. 31 is used. The condensation comes in through *i* and passes down to the thermostatic cell inside the casing *T*, whence it escapes when the trap is open. With a view to keeping the drip from freezing, casting *D* is used; pipes *b* and *i* pass clear through *D*, while a passage inside connects the two lengths of *P'*. Thus, the steam in pipes *P'* keeps the casting, and therefore the drip pipe, always hot; *w* is a blow-off valve; its casing *C* is provided with a sediment pocket in which any scale and dirt that may come through the pipes is collected, instead of passing down into *T*. By opening this valve the accumulated deposit may be blown through pipe *b* and discharged underneath the car.

While the contact of the hot metal *D* keeps the casing *T* warm, the latter never approaches the temperature (about 170° F.) at which the diaphragm would actuate the valve inside the trap. The supply of steam to the car is controlled by valve *v'*, so that there is always steam in *P'* to keep the drip pipe warm, even when steam is shut off that particular car. This warming of the casing *T* will permit of the trap being placed far enough below the bottom of the car to keep the discharge clear of the sheathing and yet be in no danger of freezing.

OPERATING THE SYSTEM.

85. Heating a Cold Train.—First couple up all the steam hose, and make sure that all train-pipe valves *V* and drain valves *u* and *u'* are wide open, and that all steam valves *v* and *v'* are shut. Let steam blow through the train pipe until dry steam comes out at the rear end of the train; then close the rear train-pipe valve. Next open all the steam valves, commencing with the rear car; open them not more than 1½ turns. When the pipes are all hot, leave the drain valves open about ¾ turn and shut down the steam valves to within about 1¼ turns of being closed. As in the systems previously described,

each side of the car is independent of the other, and the piping on one or both may be brought into use as desired. Remember that the steam and drain valves are under the seats near the center of the car; the valve with the large wheel is the steam valve, the drain valve having a smaller wheel.

Regulate the heat by the steam valves; about $\frac{3}{4}$ turn gives a full opening. In very mild weather, the drain valves should be entirely closed, thus retaining all condensation; the temperature can then be regulated by these drain valves, opening them for a few seconds between stations when more heat is needed. In doing this, some of the condensation escapes, making room for live steam.

86. Care of System.—The rear train-pipe valve can be left open just enough to permit hot water, but not steam, to pass out and thus keep the pipes clear of condensation. In frosty weather, the valve, if it has no leakage groove in its seat, must be left open enough to prevent the rear end of the train pipe freezing.

When cars are to be left without steam, all valves must be left open and all hose uncoupled. When approaching a station where engines are to be changed, close all valves inside the car and open the rear train-pipe valve. Blow through for about 3 minutes and then get the engineman to shut off steam.

When approaching a station where cars are to lay over, open all the steam and drain valves throughout the train, beginning with the rear car; do this 10 minutes before reaching the station. If the train is a long one, have extra steam pressure for this purpose. Five minutes before reaching the station, open the rear train-pipe valve; 3 minutes before reaching station, shut off steam. Uncouple all hose when engine is cut off.

When taking extra cars on a heated train, couple up all the hose, open the train-pipe valves, blow out the train pipe of the fresh cars, and then proceed to heat them up as just described. If the cars are intended for the front part of the train, blow steam through them from the engine before coupling up to the main train.

CAR EQUIPMENT: HOT WATER.

87. Steam Supply.—Fig. 32 illustrates the Consolidated Company's standard hot-water system as used in conjunction with the Baker heater or similar apparatus. This drawing is not a strictly accurate representation of the installation as actually seen on the car, the disposition of some of the pipes being altered for the sake of convenience and to bring them all into view; the drawing shows in effect what the plant is like.

Steam in the train pipe is controlled by the valve *V* nearest the engine, passing thence to the car from the fitting *t*, through *P'* to valve *v* which controls the supply to the heater. From *v* it passes through pipe *a* to the far end of the heating jacket *J* (or standard drum, as the Consolidated Company terms it,) which it enters. After traversing the length of the jacket, it passes out at the other end by pipe *b* and goes through the hot metallic drip *d* to the drain valve *u*. This valve *u* is provided with the extension handle shown, to be operated inside the car; it is an ordinary hard-seat valve, but has a special feature in the shape of a slot in the seat that can be controlled by a setscrew. The end of the screw projects into this slot, and by screwing in and out can be made to decrease or increase the passage for drainage at will. By opening the valve full, any obstruction may be blown out, and when closed the setscrew can vary the opening in the seat and thus secure all the advantage of the trap shown in Fig. 31. Another feature of importance is the drip fitting *d* which connects with the steam pipe *P'*; it will be perceived that as long as steam is on, a portion of it gets into the drip and so prevents any freezing of the condensation at that point.

88. Hot-Water Piping.—To follow the course of the circulation in the piping, start at the heater *S*: Water rises from the top of the heater coil up through riser *R* to drum *D*, whence it comes down through *p*, then along the car and across through pipe *l* and into the heater end of jacket *J*. The pipe *l* runs into *J* through the fitting *c* which connects with the header *e*; this together with header *e'* enables the two

Fig. 82.

copper pipes *j* to form a circuit. Thus, water comes in through *l*, flows along and back through pipes *j* and out again through *c* (around the *outside* of *l* this time), whence it ascends and runs along the lower pipe *p* to the end *F* of the car; it turns at *g* and comes back through upper *p*, crosses the car through pipe *2* and into the heater end of jacket *J*, thence along and out at the far end and across the car through *3*. Then it ascends and runs to end *F* of car, makes the bend *g'* and returns, drops down and crosses the car by pipe *4* and enters the non-heater end of jacket *J* by means of fitting *k*; passes around a circuit *j'* similar to the one at the other end of the jacket, and then through pipe *5* to the other side of car, where it goes to the end *L*, turns at *g'* and comes back through upper *p* and crosses by pipe *6*, entering drum at non-heater end, passing through along *6'* and out through *6''*, and back through left upper *p* to the heater coil, and ascending and passing out at the top into the riser *R*. Thus the circulation, which is a closed, or sealed, one, goes on continuously.

As previously remarked, Fig. 32 is merely a diagram of the piping, showing the circulating action, the details being absent. We may state, however, that each of the inflow pipes forms a drop or loop before entering the jacket *J*, and that each of these loops should have a fitting that contains a plugged back outlet through which to remove the dirt. When the special filler cock, Fig. 33, is used, it must be placed at the bottom of one of these loops and in the circuit near the Baker heater; this cock should have two plug cocks in its side openings. The loop that carries this filler cock need not have the fitting above alluded to. All the outflow pipes rise when leaving the jacket. The expansion drum is provided with the safety valve *v'*, set for 125 pounds per square inch. To adjust the pressure, slacken the nut on the top of the device, and then screw down the plug to increase the pressure, and unscrew it to lessen same. Then lock by means of the nut. If the spring inside should get coated with salt deposit, remove the whole fitting from the drum and soak it in hot water; clean the seat of the valve and replace.

FILLER COCK.

89. The special filler cock is shown in section in Fig. 33. It should be placed in the lowest point of the system and as near the Baker heater as practicable. The circulation piping is connected at *a* and *b*, the latter being the end nearest the Baker

Fig. 33.

heater; *c* is the main cock, and *d* and *e* two draw-off cocks. The figure shows the device in its usual position—open.

To blow out obstructions in the heater pipes, close the cock *c* and open *d* and *e*. Connect steam with *d* and leave *e* open until everything is thoroughly blown out.

To fill the pipes, close *c* and pump water in at *d* until it flows out clear and freely at *e*. Continue this until air and dirt have been driven out of the pipes. Then close *e* and *d* and open *c*, bringing the device into the position shown in Fig. 33, which is its condition at all times except when conducting the above operations of blowing out or filling the pipes. The position of each of the cocks is denoted by a groove on the end of the shank, each groove running in the same direction as the opening in the cock.

STEAM TRAP.

90. Fig. 34 shows the trap used in connection with the heating jacket *J*, Fig. 32. It is arranged so as to be applied either to vertical or to horizontal pipes, the present figure showing the former case; if a horizontal connection, the drip pipe will connect at *b*, while *a* will be plugged. A chamber is provided to catch the sediment, which can be blown out through

valve *c*. The casing is hinged and fastened at *d d*, so that it can be opened and the thermostatic cell, or the valve and its seat, readily removed.

The trap may be adjusted to discharge at any temperature by means of the adjusting screw *e* and locknut *f*.

OPERATING THE SYSTEM.

91. To heat the train, open the steam valve slowly until it is wide open. Have the drain valve open for about 1 minute when steam is first turned on, and then close it. Should it not

Fig. 34.

be found to discharge enough condensation, open it a little more to increase the discharge. The temperature of the car may be adjusted by means of the steam valve. When steam is not being used, all valves should be left open. The above directions, except those relating to the drain valve, apply when the trap, Fig. 34, is used.

CAR EQUIPMENT: HOT WATER.

(COMMINGLER SYSTEM.)

GENERAL DESCRIPTION.

92. In this system the Baker heater pipes are used, as before, but instead of the steam heating the water by passing through jackets inside of which run the heater pipes, it actually mingles with the water it is intended to heat; hence, the name given to the system. In heating by means of jackets, it generally happens that some of the steam discharges before being condensed; in the present system, however, the steam is all condensed and brought down to the temperature of the circulating water before it is discharged. Thus, much less heat is wasted. The present system is an **open circulation** one, as distinguished from those already described, wherein the circulating water remains the same, having no outlet nor inlet while the system is working, being shut off, in fact, from all communication with air, steam, or water, and therefore spoken of as a closed, or sealed, circulation.

Fig. 35 shows the piping and fittings used in the *commingler* system. Steam is taken from the train pipe P at the fitting t, whence it passes through pipe P' to the side of the car and runs to the heater end, where it turns upwards until it reaches fitting t'; thence it passes the dial cock c and ascends to a point about level with the top of the expansion drum, making the turn at f and descends to the commingler C, just before reaching which it passes through the strainer j. Entering the commingler, it mixes with the water, as hereafter described; the heated water leaves the top of commingler C and goes through the riser R into the expansion drum D. From the drum it descends through the downflow pipe p and makes the circuit of the car as indicated by the arrows. The steam crosses the car through pipe *1* and recrosses it on its return through pipe *2*, entering the bottom of the heater coil at d, passes up through the coil and out at d' into the bottom of the commingler, and thence into the drum again.

Fig. 35.

In this system there is a continual addition being made to the amount of water in circulation, owing to the constant condensation of steam in the commingler, as a result of which the drum *D* gradually fills. When the water in it rises to a certain height, it overflows into the pipe *o*, through which it passes down and along the car to the fitting *t* in the train pipe, and thence out through the drip pipe. As the connection for the drip pipe is close to the live steam in *t*, the drip cannot freeze.

Water is kept from running back from the drum to the train pipe, when changing engines or when using fire instead of steam, by carrying the pipe *P′* above the level of the water in the drum and then bringing it down again to enter the commingler. In the fitting, *j* is a swing check-valve opening toward the commingler, thus preventing the water passing back from the latter up pipe *P′* and so to the train pipe. So, also, if the train were to part or the train pipe become uncoupled, the pressure of steam in the expansion drum would force the water through *R* and *P′* to the train pipe but for this check.

When fire is being used in the heater, instead of steam, the cock *c* must be kept closed, as must also the trap cock *k* in the overflow pipe *o*. The purpose of the pipe *q* is to allow air to enter the steam pipe *P′* to prevent a vacuum forming when steam is shut off from the system and the steam in the train pipe condenses. As soon as a vacuum forms, the diminished pressure in the train pipe and steam pipe allows atmospheric pressure, which is then the greater, to force air through the drip pipe and along the overflow *o* and through *q* into *P′* after lifting the check-valve at *h*; in this way air enters the train pipe on each car. As a matter of fact, a small quantity will also enter the train pipe through the groove in the seal of the rear train-pipe valve; but this, in itself, will not admit sufficient air promptly to the train pipe. On the top of the overflow pipe *o* is a cap, open at the side, so designed that it will allow the water to pass off when a certain level has been reached, but at the same time prevent the escape of water thrown up by the action of the commingler. This pipe *o* should be at least 12 inches from the riser *R* inside the drum.

COMMINGLER.

93. Fig. 36 shows a section of the commingler. Water from the heater coil enters through the pipe d' and leaves through R on its way to the expansion drum. Steam from the train pipe enters at p' and passes down pipe a, escaping thence into the body of the commingler through the small holes shown in the nozzle b. The admission of steam to the body of the water in this manner prevents the noise that is experienced when steam enters a body of cold water directly and without being previously broken up, as is done by these holes. Sometimes a portion of the interior of the casting is filled with small pebbles surrounding the nozzle, the effect being to still further break up the steam, which has to force its way through these pebbles before striking the main body of water in the casting.

d'

Fig. 36.

OPERATING THE SYSTEM.

94. Heating a Cold Train.—See that all the steam hose is coupled up and all the train-pipe valves open. Then turn on steam from the engine, and when it blows freely out of the rear-end coupler, partly close the rear train-pipe valve, leaving it open just enough to keep the rear end of the pipe from freezing. Next, open the trap cock full in the heater room, and the dial cock just enough to heat the car to the proper temperature. When steam cannot be obtained, a fire must be started in the heater, observing to shut the dial cock and trap cock.

95. Care of System.—If the overflow pipe from the drum is clear, the condensed water will begin to escape soon after the steam is turned on. It should be noted whether this occurs or not. When within about a mile of a station where the engine is to be cut off or where cars are to be taken on or off, the rear train-pipe valve should be opened and

steam shut off at the engine. When approaching a point where the train is to be delivered up to another road, shut the dial cock and trap cock before opening the train-pipe valve at the rear end of the train pipe. This should also be done on every occasion when steam is to be shut off for more than 5 minutes; while if the time exceeds 20 minutes, the steam hose between the cars should be uncoupled. To assist in carrying out this rule, steam should not be shut off at the engine without first notifying the trainmen. Whenever a train is without steam, the train-pipe valves should be left wide open. Trainmen will note this when setting out cars. Whenever it is necessary to use fire in the Baker heater, the dial cock and trap cock must be closed, and if the car or cars are at the rear of train, the steam hose must be uncoupled between the cars themselves, and also between the first dead car and the last car using steam.

CIRCULATION.

96. Circulation Stopping.—When the circulation fails and the trainman is unable to restore it, and finds that the car is getting cold, he should shut the trap cock and open all drain cocks under the car; this will allow water to run out and live steam to enter and heat the car.

97. Car Losing Water.—If a car loses its water and the circulation stops, shut the trap cock until the system fills up again by steam condensing. If this does not answer, fill up at the next station stop, shutting the dial cock and opening the trap cock when nearing that station.

98. Overflow Blocked.—If steam has been on continuously for any length of time and the overflow is not hot, it is an indication that it is stopped up somewhere. Since with an obstructed overflow water cannot discharge from the drum, the result will be to prevent hot water circulating in the car. When such a case arises, try the effect of reversing the handle of the trap cock, turning it around from "open" to "open"; then, if the small hole of the cock is choked up, the dirt will be

carried out and the pipes get hot. If unable, however, to remedy the trouble, and the demand for heat is imperative, shut off steam at the dial cock and stop at the next station. Here drain half the water out of the drum, close the trap cock, and light a fire in the heater. If the drum is inside the car, this can be done without waiting for the next stop.

99. Car Getting Cold.—If while steam is on, a car is found to be getting cold, first see that the dial and trap cocks are open. If so, feel if the steam pipe *P'* near the heater is hot; if it is, and the gauge shows a pressure, it is a sign that this pipe is all right. Next feel the overflow pipe; if unobstructed, it also will be hot.

100. Shortness of Water.—If a car is found to be cold, and the dial and trap cocks are open and the steam and overflow pipes are hot, feel the pipe under the commingler; if it is hotter than the down pipe or than the pipes at the other end of car, it is evident that circulation has stopped and the trap cock must at once be closed. By closing this cock, steam is kept from escaping from the drum; it will therefore condense and refill the system. If this is effectual in restoring the circulation, such will be shown by the pipe under the commingler becoming cooler.

If the weather is very cold, and circulation is not restored in time, the cross-over pipes may freeze; where this seems probable, stop at the next station and fill up the expansion drum, being careful to shut the dial cock and to open the trap cock before the station is reached. This will let out the steam and so enable water to be put in without delay; the train should then start away again without further loss of time and without waiting to see if circulation is restored. If the circulation is still found to be at a standstill, stop at the next station and open the drain cocks in the cross-over pipes, first thawing them with a torch, if necessary, and blow them out, as it may be that mud is the cause of all the trouble. If all efforts still fail, leave open these cocks and any others, shut the trap cock, and use dry steam.

CLEANING OUT THE PIPING.

101. Each road has its own rules for cleaning out its piping, both as to frequency and also the method of doing it. The majority clean them out once a year. Following is the method adopted by the Canadian Pacific Railway, who are large users of this system: Take down the commingler, disconnecting the various pipes; connect a piece of hose with the open end of the riser, and attach a pipe to end of *d* to lead the water away from the car. Then turn on water from the water main, allowing the full force to act, and the water, after making the circuit of the system, will escape out of the top of the coil through *d'* and the water pipe just mentioned. While this water is passing through the pipe, tap lightly but smartly on the pipes, particularly the cross-over pipes and heater coil. Remove the lower part *c* of the commingler, Fig. 36, and pour out the pebbles, which should be throughly washed and cleaned, preferably in a sieve under running water. Take out the steam nozzle and clean it, removing any dirt that may be inside. See that the pipes *a* and *P'* are clean, reassemble the parts, putting the pebbles in through the side when nozzle, screen, and plug *c* are in place. Have the pebbles packed as closely and compactly as possible. Disconnect the overflow and take the overflow cap out of drum; see that the openings in this cap are clean. Examine the trap cock; see that it is tight when closed and that when open a $\frac{1}{8}$-inch wire will pass through it freely. This cock should show perfectly tight under a warm-water test, using a pressure of 250 pounds kept on for 20 minutes. The dial cock should be similarly tested. If these cocks are not tight, and it is found that tightening up the flange bolts does not make them so, they require new packing. See that the check-valves at *c* and *h* are clean; they should open and shut freely and also be quite tight on the seat. Examine the strainer in the fitting *s* at the bottom of the pipe *P'*. Take out the plug in the lower end of the fitting, remove the strainer, and see that it is quite clean and the holes all clear. The parts can now be connected and the pipes filled as previously directed, after

which steam may be turned into the commingler to start the circulation and free the pipes from the air that will have remained in them.

WATER-RAISING SERVICE FOR COACHES.

GENERAL STATEMENT OF THE PROBLEM.

102. Object of the System.—Until within the last few years, passengers using car lavatories have had to raise their own water supply to the faucets by means of a hand pump. Then began the practice of taking compressed air from the brake system to force this water through the faucets into the wash bowls.

103. Effect on the Brake System.—As this device involves the withdrawal of air from the brake system, it is evidently a part of the enginemen and trainmen's duties to understand the whole arrangement, so that they may readily locate any trouble that may arise. Much trouble and annoyance have been caused in the past through badly designed methods of utilizing this air, and as a rule the enginemen and trainmen were unacquainted with the piping used, and therefore could not locate the trouble at its source. There are certain appliances, such as the signal system, the bell ringer, the pneumatic sander, etc., that have always drawn their supply of air from the air-brake system, but as they draw their power from the main reservoir, there is no objection to their use, except that they entail extra work on the pump. In other words, the operation of any of these devices cannot induce a state of affairs that will be a source of annoyance to the engineer, and of, perhaps, danger to the train, and at the same time be unknown as being the cause thereof; this drawback, however, can occur with the water-raising system as originally installed. If the supply for this system had to be drawn from the main reservoir—the proper source—it would necessitate an extra train pipe with the necessary hose couplings. In default of this, the supply had to be taken either from the ordinary

train pipe or else from the auxiliary reservoirs, and this latter was the course adopted.

It is known that the brake will not set as long as the pressure in the auxiliary and train pipe remain equal, but if the train-pipe pressure is reduced or the auxiliary-reservoir pressure increased, the triple valve will be actuated and set the brake; also, a reduction of auxiliary pressure when the brake is set will cause the brake to release. We can thus see the objections to a system that takes air from the auxiliary, and that also, through leakage, is liable to allow air to go back into the auxiliary. In the one case it may release the brakes, and in the other set them harder. In addition to these drawbacks, water might also leak through into the brake system. All this has in the past given considerable trouble.

EARLY ARRANGEMENTS OF APPARATUS.

FIRST METHOD.

104. In the first cars equipped with water-raising apparatus there were three water tanks—piped together top and bottom—and one air tank. Air was taken from the train pipe and conducted through a valve and pipe into the bottom of the air tank, from whence it passed into the upper part of the water tanks, exerting therein a pressure tending to force the water out along the supply pipe in the car. These four tanks received their supply of air when the train was recharging, and as they were each 8 feet long and 1 foot in diameter, they proved quite a drain on the pump's power. Check-valves were provided to prevent any return of pressure from the air or water tanks to the train pipe, but all such valves are liable to leak more or less at times, and when this was the case, pressure from the air tank would leak back into the train pipe and by raising its pressure would release the brakes. In ordinary stops, where the application of brakes last only for 10 or 15 seconds, leaks of small magnitude will produce no ill effect, whereas they will be a serious item when the train is working down long mountain grades where the brakes must be kept on for 30 to 40

minutes at a time. Long intervals such as these will of course enable even small leaks to release the brakes against the engineer's intentions. In like manner, also, water can leak back into the brake system, where it will freeze the triples and so obstruct, more or less, the passage of air in the train pipe.

IMPROVED METHOD.

105. The foregoing consideration led to the introduction of another arrangement, in which, although air was still taken from the train pipe, it was permitted to do so only during station stops of several minutes duration. This procedure was a recognition of the undesirability of taking air from the brake system at any and all times. It was so arranged that when the tank lever was pulled out for the purpose of refilling the tanks, communication was shut off between the air tank and the water tanks, and also between these latter and the distributing pipes; at the same time the supply pipe to the water tank was opened and communication established between the water tanks and the atmosphere. By this arrangement water could be run freely into the water tanks, while at the same time the water remaining in the distributing pipes and the air in the air tank were prevented from escaping. On pushing in the lever, the supply pipe became cut off from the water tanks, the latter were shut off from the atmosphere, and communication was once more opened up between the air and water tanks and between the latter and the distributing pipes.

The air in passing from the air tank to the water tanks had to go through a reducing valve or regulator, which cut down its pressure to the desired amount; 70 pounds was carried in the train pipe, but this was much more than required in the water system. Using it at that pressure would only result in a great rush and splashing when the faucet was opened. Consequently, this valve was set to reduce the pressure down to 20 pounds.

A shut-off cock was now placed in the pipe leading from the train pipe to the air tank, and, as remarked, this cock was enjoined to be opened only when standing at stations, and to be kept closed when the train was running. Just beyond this shut-off cock, between it and the air tank, was a stop-cock; to the nipple

leading out of this cock a hand pump could be attached and air pumped into the air tank on occasions when air pressure could not be obtained from the brake system. The success of this method depended on the trainmen obeying the injunction to keep the shut-off cock closed while the train was running. Sometimes it was neglected to charge the system while the train was at stations, or perhaps the air pipes were not tight and therefore air was lost through leakage. In such cases, seeing the pressure go down, the trainmen, instead of pumping it up by hand, were wont to open the shut-off cock and take air from the brake system. In some cases they would know enough of the action of the apparatus to take air very gradually, thus not entailing any ill result, for the pump governor would keep the pump going and so keep the train-pipe pressure from reducing rapidly enough to apply the brakes. Often, however, the cock would be opened abruptly and the brakes applied as a result—sometimes "in emergency."

Again, the regulator would not always act properly, and sometimes it would prevent any passage of air from the air tank to the water tanks, thus taking away the lifting force necessary to put water into the basin. Often the shut-off cock would be left open, more or less; in such cases, if the automatic valve was not tight on its seat, it could not prevent the return of air from the air tank, and thus on occasions of reducing train-pipe pressure to apply brakes, air would go back past the shut-off cock into the train pipe and release the brakes again. This would make the arrangement as objectionable as the one first described.

MODERN ARRANGEMENTS OF APPARATUS.

FIRST METHOD.

106. General Description.—Fig. 37 shows one of two modern methods used for raising water; it differs from the two already described in the fact that it draws the air pressure from the auxiliary reservoir instead of from the train pipe. This was done so as to avoid the evils resulting from taking the pressure from the train pipe.

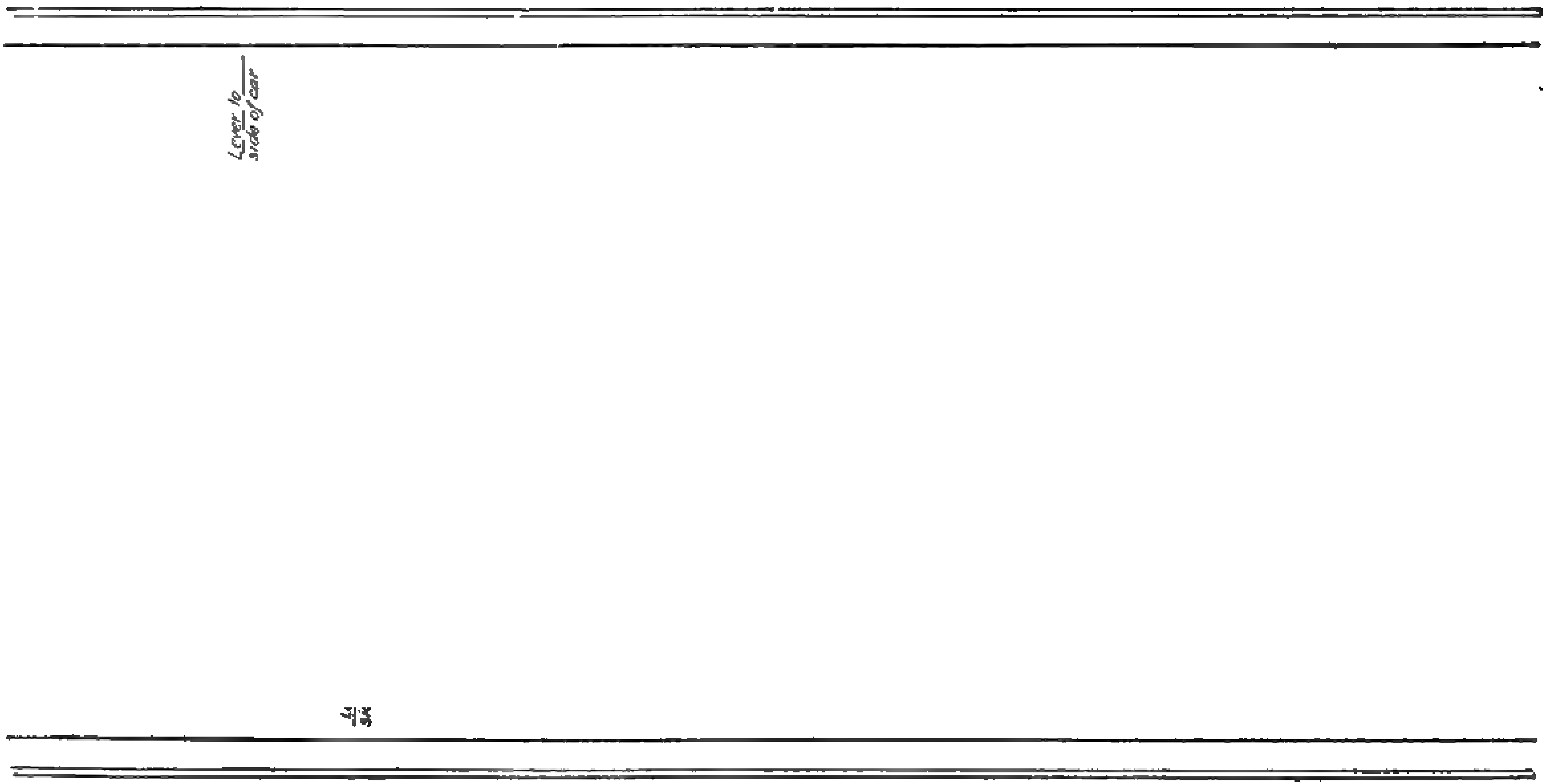


FIG. 37.

In the illustration, *A* is the auxiliary reservoir; *B* the brake cylinder; air passes from *A* through pipe *P* to the air tank *C*, first passing through the governor valve *q*. The purpose of this valve is to prevent air under 60 pounds pressure passing through from the brake system, thereby insuring that sufficient pressure will accumulate in the auxiliary reservoir to test the brake before the supply is drawn on by the air tank. Air, on leaving the air tank to go to the water tank *D*, must pass through the reducing valve *r*, and thence through pipes *p* and *p'* to the water tanks. The reducing valve *r*, which corresponds to the regulator mentioned in connection with the earlier systems, is adjusted to 20 pounds, that being the limit of pressure allowed to pass to the water. The passage of air in this direction is controlled by cock *c*, whose levers *l* are operated from either side of the car. The other cock connections are the same as in the earlier systems. As regards the time required to charge the tanks *C* and *D*, it will be borne in mind that all the air that goes to these tanks must first pass through the feed-groove in the triple valve. The governor *q* simply prevents any air going through to the air tank until a pressure of 60 pounds has accumulated in the auxiliary.

AIR-PRESSURE GOVERNOR.

107. Fig. 38 shows in sections the latest form of air-pressure governor. The parts as marked are *a*, the body; *b* and *c*, the upper and lower caps; *d*, the diaphragm; *e*, the diaphragm valve, held in the diaphragm plate *d'* by means of the nut *f*. The diaphragm is held down air-tight by the ring *g*, screwed down by cap *b*. The pressure on diaphragm stem *e* is supplied by spring *i*, the tension of which is regulated by the plug j, locked in position by the jam nut *k*. The supply valve *l* is held on its seat *n* by spring *m*. Air comes in at *A*, and after passing valves *e* and *n* goes out through *q* to the air tank, the other side *A* of the governor being piped to the auxiliary reservoir. The valve *e* is moved up and down by air pressure on the diaphragm plate *d'*, the diaphragm allowing flexibility of motion while also preventing the pressure from getting on its top side. The spring *i* is screwed down by means of the plug *j*

until it requires an air pressure of 60 pounds per square inch to raise the diaphragm, and so lift valve *e* off its seat. When this occurs, the air flows down past *e* and forces the valve *n* down against the resistance of spring *m*, and passes on through port *q* to the air tank. Air cannot come back from this tank to the

Fig. [illegible]

auxiliary reservoir on account of the valve *n* acting as a check, for if the pressure in the auxiliary were to get less than that in the air tank *C*, the greater pressure in the latter would keep *n* firmer on its seat. Of course, if valve *n* leaks, its value as a non-return check is gone; and this is one of the things that must be watched, for then the air will flow back into the auxiliary and probably cause the wheels to be skid. The hole *s*

is to allow the escape of any air that may happen to pass through to the upper side of the diaphragm, thus preventing the accumulation of pressure there.

REDUCING VALVE.

108. The **reducing valve** *r* is shown in section in Fig. 39. Connection with the air tank is made at *C*, and at *D* with

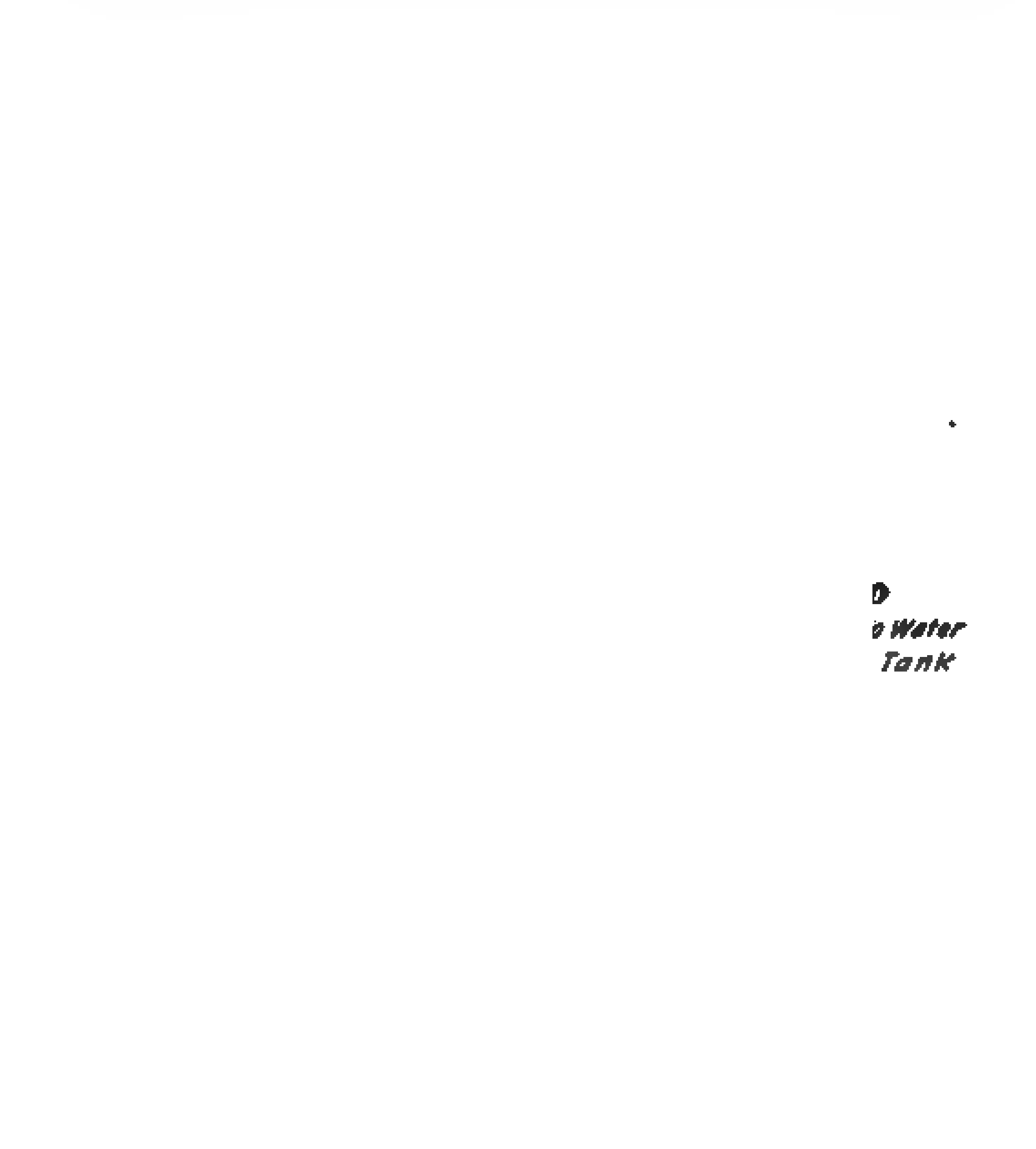


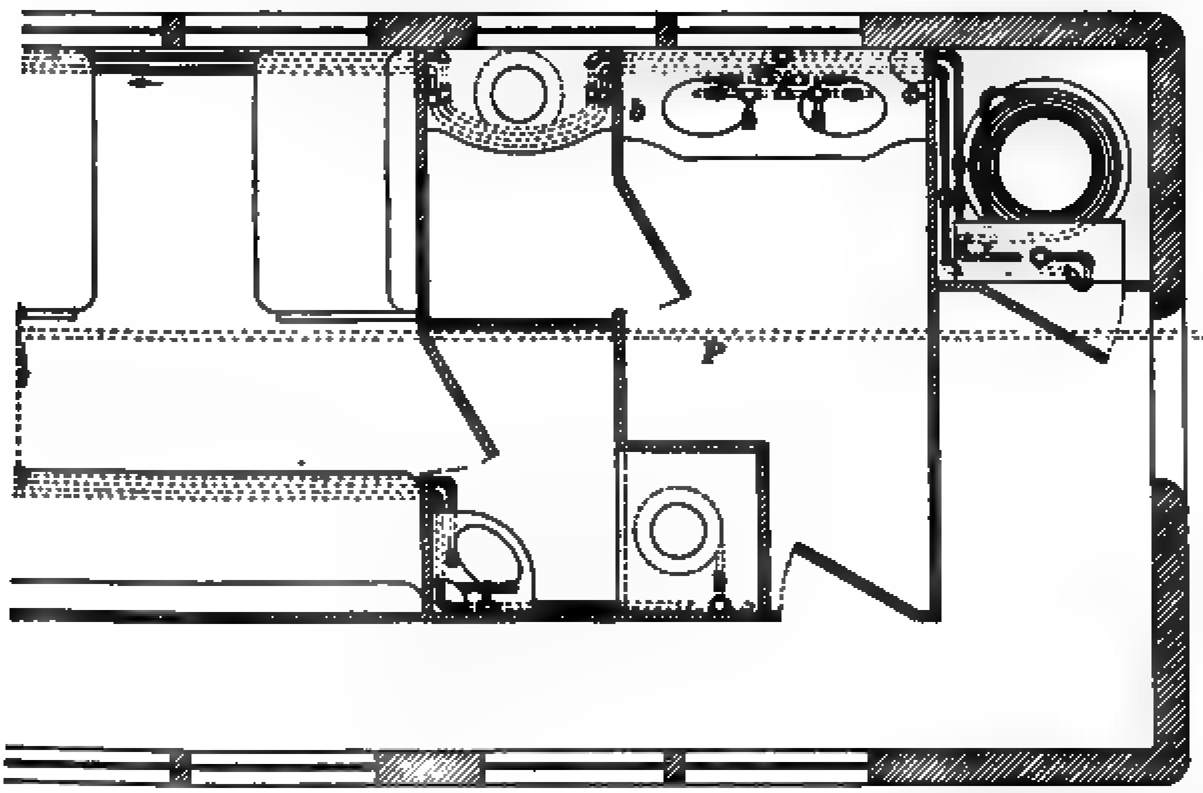
Fig. 39.

the pipe leading to the water tank. The object of this valve is to reduce the pressure to 20 pounds per square inch before it goes into the water system. In the figure, *a* is the valve body; *b* and *c*, the upper and lower caps; *d*, the diaphragm, and *d'*,

the diaphragm plate, forced down by spring *i* encircling the stem *h*. The supply valve *l* is held on its seat by the spring *m*. Now, when all pressure is off, the diaphragm *d* is down and the end of its stem *h* presses on the stem of the supply valve *l* and so keeps the latter off its seat ready to admit air to the water system. This air comes from the air tank or reservoir at *C* and passes up ports *o*, *o* and past the seat of valve *l* and so into chamber *r*, and thence through passage *q* to the water tank. When the pressure in the tank, and therefore in chamber *r*, exceeds 20 pounds per square inch, the pressure on the diaphragm becomes greater than the resistance of spring *i* and moves it up, thus removing the pressure from the top of the valve stem *l* and allowing valve *l* to seat and shut off all further flow of air to *r* and the water tank. When, through leakage or the use of the lavatory, the pressure in the water tank and chamber *r* falls below 20 pounds, the diaphragm is pushed down by the spring *i*, thus unseating the valve *l* and once more allowing air to flow past *l* into *r* and on into the water tank *D*. If the face of *l* should get dirty and not seat tightly, an excess of air will pass into the water system, unduly robbing the auxiliary reservoir and causing a violent splash when passengers open the faucets.

SYSTEM NOW IN USE.

109. General Description.—The system now being installed involves many improvements over those already shown, both as regards the water and also the air supply. It is illustrated in Fig. 40, wherein it will be seen that with a view to economizing space, a single water tank replaces the three tanks hitherto used, and is placed in line with the air tank. Of the views here given, (*a*) is a plan of part of the car; (*b*), a side view; (*c*), a cross-section through end *E* of the tank box; (*d*), a side view of the right-end portion of the car; (*e*), an end view of the same, showing the heating arrangements. Of the parts lettered, *A* is the auxiliary reservoir; *B*, the brake cylinder; *C*, the air tank; *D*, the water tank; and *P*, the train pipe belonging to the brake system. The cold-water fittings are: *a*, view (*a*), the shut-off cock in the supply pipe; *b*, view (*d*), the stop-cock


b
P

and waste cock for the closet; *c*, *c*, the stop-cocks for the wash bowls; *d*, the stop-cock for the faucet; *e*, the stop-cock for the fire-hose. Among the hot-water fittings are *f*, view (*a*), the shut-off cock in the supply pipe; *g*, *g*, view (*d*), the stop-cocks for the wash bowls; *h*, the shut-off valve for the hot-water coil; *i*, the check-valve in the supply pipe leading to the hot-water coil *j*; *k*, the shut-off valve in the hot-water supply pipe leading from the heater; *l*, the drip stop-cock in the pipe leading from the hot-water coil; *m*, the safety valve on top of the hot-water tank *n*. The main shut-off cock is marked *o*, view (*b*), and is operated from the inside of the car; *p* is a three-way cock serving to admit water into the tank *D* when filling, and also, subsequently, to admit air from tank *C* to *D*; *q* is the air-pressure governor; *r*, the air-pressure reducing valve; *s*, the drip cock in the air tank; *t*, view (*a*), the drip cup, with strainer, in the air pipe leading from the auxiliary to the air governor; *u*, view (*c*), the waste pipe and valve from the water tank; *v*, the air vent from the water tank; *w*, view (*a*), the stem for operating cock *p*; *x*, the check-valve in the air-pressure pipe; *y*, the tank filler.

ACTION OF APPARATUS.

110. Air passes from the auxiliary reservoir *A* through the pipe *1* to the governor *q*, which allows no air to pass until a pressure of 60 pounds is reached. Thence, air goes through pipe *2* to the air tank *C*, which it leaves by way of pipe *3* on its passage to water tank *D*. After passing through the reducing valve *r*, the air reaches the three-way cock *p*, which controls its entry into tank *D*. After passing this cock, it enters the top of tank *D*, first passing the check-valve *x*. From tank *D* the water passes through the main shut-off cock *o* on its way to the wash rooms. If the pressure from the faucets should be too great, it can be controlled by the cocks *c*, view (*d*), underneath the wash stands. Closing the cock *o* shuts off the whole water supply to the car. Water can be shut off from either end of the car separately by means of cocks *a* and *f*, view (*a*), the former for cold water and the latter for hot. By means of cock *k*, view (*d*), the hot-water supply can be shut off entirely. The hot-water tank *n* may be drained off by means of the cock *l*.

OPERATING THE SYSTEM.

111. Renewing the Water.—To fill the water tank, the air supply from the air tank must first be shut off, and the air that is already in the water tank allowed to escape. This is accomplished by turning the stem *w* of the three-way cock to the right, which at the same time opens the way for water to enter the tank when put into the filler *y*. Generally, a hose is used for this purpose; if buckets are used, a funnel supplied for the purpose should be attached to the filler. If water is exhausted in tank *D*, it is indicated by air coming out of the faucets.

112. Testing the Valves.—One of the important points in running this system is to see that the reducing valve *r* is in good working condition, as otherwise full air-tank pressure will pass to the water, which will not only be an annoyance in itself, but will also waste air, the renewing of which entails extra work on the pump.

To test the reducing valve, charge the air and water tanks, and note the pressure indicated by the gauge in the wash room; it should not exceed 20 pounds.

To test the governor, charge the tanks as above; the black gauge hand should show 20 pounds, and the red hand, 70 pounds. Then close the angle cocks at both ends of car and disconnect the hose; next open the release valve in the auxiliary reservoir and draw off all air pressure from the auxiliary and the train pipe; close the auxiliary release valve for a few minutes and again open it. If no pressure has accumulated, the valve *l*, which prevents return of air, is tight on its seat. The actual pressure to which the governor is adjusted can be ascertained by attaching a gauge to the auxiliary.

113. Various Troubles Encountered.—As already remarked, if air without water escapes when the faucet is opened, the water tank requires refilling. If neither air nor cold water escapes, see that all the cocks *a*, *c*, and *d* between the water tank and wash stands are open. If hot water fails to appear, see that cocks *f* and *g* are open and also valves *h* and *k*. Cock *l* should be shut; if open, it will empty the hot-water tank.

Sometimes it may happen that although the cocks are all right and there is plenty of water in the system, yet no air pressure is apparent. In that case, the strainer and drip cup *t* in pipe *1* should be examined, and also the governor and the reducing valve. The latter should be examined first when trouble arises through the flow being either too weak or too strong, as it can, in the event of dirt or bad adjustment, give rise to either of these troubles. It is a good plan to drain the air tank after each trip by means of the drain cock.

THE ELECTRIC HEADLIGHT.

THE PYLE-NATIONAL ELECTRIC HEADLIGHT.

DESCRIPTION AND OPERATION OF ENGINE AND DYNAMO.

INTRODUCTORY REMARKS.

1. In keeping with the general advance made in locomotive construction, there has been created in the last few years a demand for a headlight of greater illuminating capacity than the old-style oil lamp. While it will be some time, perhaps, before freight engines are provided with electric headlights, yet the general adoption of this light for passenger engines makes it essential that those responsible for the care and operation of locomotives gain a knowledge of this apparatus sufficient at least to insure the proper handling necessary to avoid its failure on the road. This headlight passed the experimental stage some years ago, and is now used to such an extent as to admit of its being classed with the more familiar apparatus, the injector, lubricator, air brake, etc.; and, with the same care and intelligent operation, it will render as efficient service as any part of the locomotive, or any of the locomotive attachments.

GENERAL DESCRIPTION.

2. Briefly, the electric headlight consists of a self-contained engine and dynamo and an arc lamp. The engine provides the power necessary to operate the dynamo, which in turn generates the electric current that operates an arc light that is

provided with a suitable reflector such as is used with the ordinary oil lamp. The engine and dynamo are direct-connected, the connection being made through the medium of a steel shaft revolving in suitable bearings that are carried by a body or framework of iron. This frame, though lightly constructed, is yet of ample strength, as the parts are perfectly balanced and have a rotary movement throughout. By this explanation, it will be understood that the motion (1,800 revolutions per minute) of the dynamo is directly transmitted from the engine without the intervention of any speed-multiplying device such as belt, pulleys, gears, etc.

THE ENGINE.

3. General Description.—The engine is of the turbine type, compounding the steam four times, and may therefore be called a *quadruple compound turbine engine.* This engine has some ingenious features in that it has no wearing surfaces in either steam chest or cylinder, and therefore requires no internal lubrication; hence, no sight-feed lubricator is provided for it in the cab. It has no reciprocating parts, hence, it can be, and is, perfectly balanced. While it provides an increased piston area for each succeeding expansion of the steam, as do all compound engines, it also provides a decreasing piston velocity, as the pressure of the steam is decreased by each successive expansion, the speed of the last pistons being equal to but 55 per cent. of the speed of the pistons against which the steam is first used.

In Fig. 1 is shown a vertical section, cut lengthwise through the machine, from which a very good idea of the construction and relative positions of the parts can be gained. The turbine wheel on the right, marked *2*, is fastened solidly to the main shaft *S* and contains four sets of buckets. The outer set *a* is at its extreme outer diameter, while the three remaining sets of buckets, marked *b*, *c*, and *d*, respectively, also in circular form, are inside the outer row. Each row of buckets, beginning with the row *a*, has a gradually decreasing speed, the peripheral speed of the last row *d* being but 4,000 feet per minute against 7,200 feet per minute, the speed of the outer row. The steam

Fig. 1.

entering at *A* passes through two ports *f* in the governor stand *35*, strikes the face of the first row *a* of buckets, and as the wheel moves forward, it allows the steam to exhaust or pass out through the bottomless buckets into a series of stationary exhaust passages *h*, the direction of travel of the steam being in a measure reversed. These exhaust passages are so shaped as to change the movement of the steam in a forward direction again, and discharge it into the second row *b* of buckets, which, like the low-pressure cylinders of a compound locomotive, are of greater capacity than the first, and, in addition, are moving slower because of their decreased distance from the shaft *S*. A second force is thus exerted on the wheel. The steam exhausts from this second row of buckets into a second series of exhaust passages *i*, which causes it to impinge against the third row *c* of buckets. Exhausting again into a third series of exhaust passages *j*, it is directed against the fourth row *d* of buckets, the final exhaust being made into a central chamber *E* enclosing the main shaft and thence to the atmosphere through the connection *V* shown just below the main shaft.

4. By referring to Fig. 2, the manner in which the steam acts on the wheel can be plainly seen. This view shows a section of one-quarter of the wheel, cut through from the outer edge to the center, the back half of the turbine being removed in order that the rows of buckets *a*, *b*, *c*, and *d* may be observed. The appearance and construction of the stationary exhaust passages *h*, *i*, and *j*, which direct the steam against their respective rows of buckets, are also plainly shown. The final exhaust chamber *E* encircling the main shaft *S*, the admission port *A*, and also the steam ports or passageways *f* in the

FIG. 2.

governor stand *35* are shown. Diametrically opposite the steam inlet *A* and the exhaust passages *h*, *i*, and *j*, there is another steam inlet with a corresponding set of stationary exhaust passages. The steam thus acts at two diametrically opposite points on the wheel, hence the wheel is in perfect balance, and this arrangement eliminates all shocks such as are occasioned in an engine having reciprocating parts, the main shaft bearings carrying only the weight of the revolving parts. The general direction of the steam in its passage from port *A* to the exhaust chamber *E* is shown in Fig. 2.

The buckets *a*, *b*, *c*, and *d* are connected to the shaft *S*, and, of course, cause it to revolve with them; the exhaust passages *h*, *i*, and *j*, as already remarked, are stationary. This construction, therefore, offers no rubbing surfaces and does away with the necessity of admitting lubricant to the engine proper.

5. The Engine Governor.—The governor, Fig. 1, is of the well-known centrifugal type. The governor weights *31* (two in number) are simple bell-cranks, the connection to the wheel being made by the clamp *30*. The shorter end of the bell-crank *31* extends beneath the center piece *37*, as shown, and moves it out when the centrifugal force exerted on the longer end of the bell-cranks is sufficient to overcome the tension of the governor springs *41*. This spring regulates the speed of the engine; the more rigid the spring the more difficult it is for the weights, acting through the medium of the center piece *37*, cross-arms *36*, and connecting link *34*, to close the plunger valves *38* and thus in part throttling the admission of live steam through the ports *f* in governor stand *35*. Between the center piece *37* and the cross-arms *36* we find the bearing ring *39*, a bronze ring filled with graphite. The graphite serves so well as a lubricant that, after several months' service, no appreciable wear can be noticed on the parts affected. The bushing *18* serves as a bearing to carry the steam end of the main shaft, the familiar oil ring *22* lifting the oil out of the oil cellar to the top of the shaft, where it passes along to the bearing proper. Lateral motion is prevented by the end thrust *8* resting on bushing *17*, provision being made for taking up possible wear at this point. The

bushing *17* serves to support the dynamo end of the main shaft, this bearing also being provided with an oil ring *22* similar to that of the bearing *18*.

The stuffingbox *20*, covered by gland nut *21*, serves to make a tight joint where the main shaft leaves the exhaust chamber. This stuffingbox should be packed with wicking or other suitable material. This type of engine is very serviceable, provided the governor is kept in good condition. Should the governor become inoperative when the engine is carrying a high head of steam, the speed is liable to become so great as to fracture the main wheel by reason of the excessive centrifugal force that would then be exerted upon it.

THE DYNAMO.

6. General Description.—In the construction of the dynamo, particular effort was made to simplify all parts as much as possible. The armature *13*, Fig. 1, is held in place on the engine shaft *S* by the nut *15*, screw *45*, and washer *16*, all of which are prevented from working loose by means of a smaller screw *l* in the outer edge of the washer. The armature is caused to rotate with the shaft by means of a dowel-pin *n* entering a suitable recess cut laterally into it from the shaftway.

FIG. 3.

The armature revolving at high velocity between the pole pieces *7* (which are connected by the upper and lower fields *152*), generates the electricity, which it delivers to the commutator *12*; from which it is connected by two brushes *B*, *B*, Fig. 3, one of which is shown in *B*, Fig. 4. These brushes, held in suitable brush holders *H*, Fig. 4, transmit the current to the lamp by aid of suitable wires insulated with a non-conducting covering. The casing *14*, Fig. 1, protects the dynamo from

dust and rain in summer, and snow and ice in winter, and perhaps the one thing most necessary to the proper working of the headlight is scrupulous cleanliness in all parts of the dynamo. The voltage, or pressure,* of the current generated by the dynamo is so low that it will not injure a person in the least; therefore, the operator need have no fear of receiving an

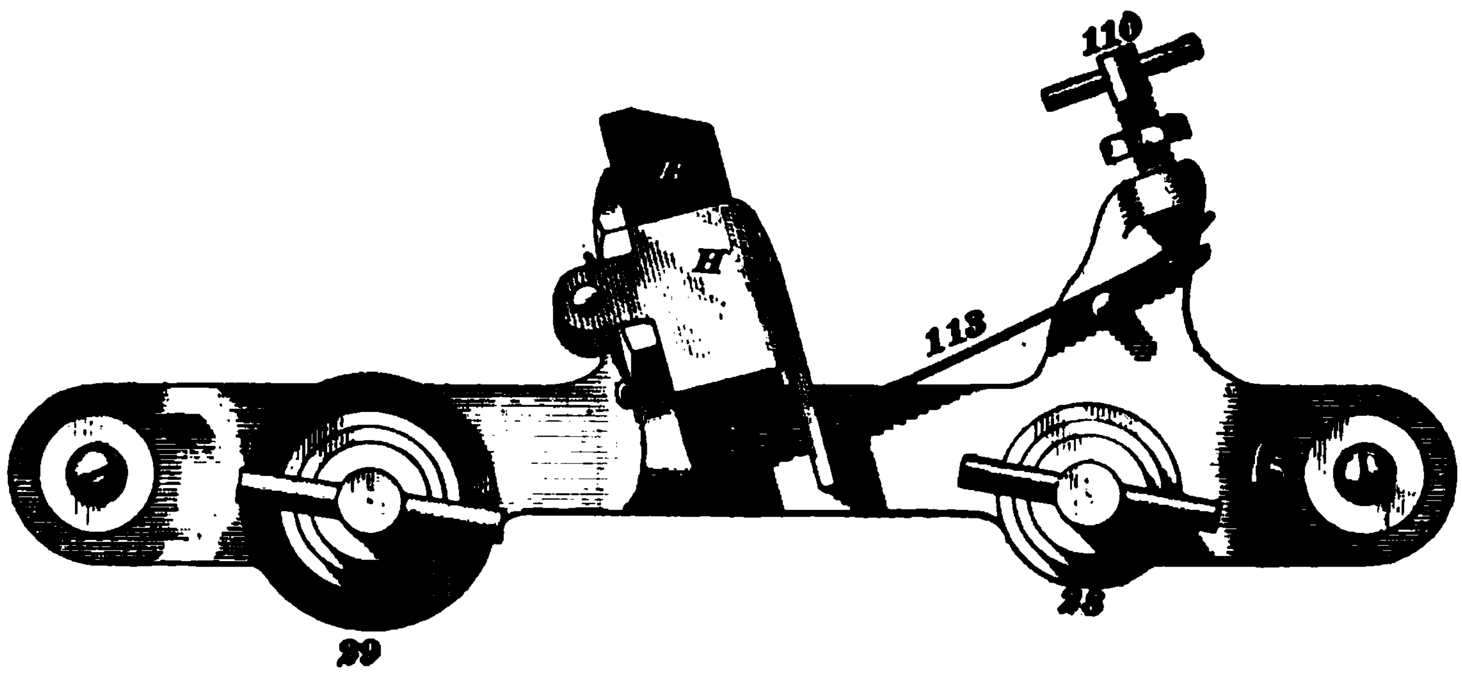


FIG. 4.

injurious shock. In fact, no shock can be felt when direct and intentional contact is made. One thing should be clearly understood, however, and that is, a watch should never be brought closer than 18 inches to the dynamo, as it is very apt to become magnetized, thus destroying its usefulness as a timekeeper until demagnetized. It is a good plan to keep your watch as far away from the pole pieces of the dynamo as possible; then no harm can result.

PRECAUTIONS FOR INSTALLING ENGINE AND DYNAMO.

7. To insure a sufficient quantity of steam, the steam connection to the boiler should be 1 inch in diameter and the steam should be taken from the highest part of the dome. If the

*The voltage, or pressure, of a current of electricity is the force that causes the electricity to flow through the wires, just as steam pressure causes steam to flow through pipes. The unit of steam pressure is the pound per square inch; the unit of electrical pressure is called the volt, which was named after Volta, a great Italian scientist.

apparatus is placed just in front of the cab, the steam-supply pipe should be covered with suitable lagging, or, if placed close to the stack, it is advisable to run the steam-supply pipe under the jacket to avoid condensation. If the pipe is not put under the jacket, it will be well to run it just inside the hand railing and on a line with it, in preference to carrying it down to the running board and then up again, as with the last-mentioned mode of piping it is impossible in cold weather to deliver steam to engine in proper condition. The exhaust pipe should be $1\frac{1}{2}$ inches in diameter, and the discharge end should be about flush with the top of nozzle tips in front end. If a 2-inch pipe is used inside the front end, the exhaust will make less noise and will have a lighter action on the fire.

CARE OF THE ENGINE AND DYNAMO.

CARE OF ENGINE.

8. As already mentioned, there are no wearing surfaces inside the engine to lubricate. However, an oil plug is placed in the top of the engine, and this should be removed about once a week and three or four tablespoonfuls of engine oil poured in. This oil is not to lubricate the parts, but to serve as a preventative of corrosion. Mineral oils will remove and prevent rust much better than animal oils; hence, mineral oils alone should be used for this purpose. The main bearings *17* and *18*, Fig. 1, carrying the weight of the turbine wheel, armature, commutator, and shaft, require the best grade of oil, the heavier quality cylinder or valve oil being best adapted to this service. Care should be taken not to fill the inside bearing *17* too full, as it will be thrown out of the end of the cellar on to the armature by the motion of the locomotive, and oil injures and eventually will ruin the armature. A quantity of oil sufficient to reach the ring *22* best answers the purpose, the ring carrying it up to the top of the shaft, the surplus falling back into the cellar. The outer bearing *18* should be filled each trip to about the height indicated in Fig. 1, and the plug *6* should be tightened down

by the screw *118*, as exhaust-steam pressure reaches the oil supply in this bearing.

On the improved engines, this cellar has been supplied with a drain pipe to lead off the water that accumulates under the oil. Where this pipe is not used, some means of removing the condensation must be applied before the cellar is filled. It is very important that the casing be thoroughly drained before starting the engine, and that the steam be turned on slowly, so as to allow time for the removal of condensation and for the working parts to assume the natural positions incidental to changes of temperature before a high speed is attained. As the speed of all moving parts, both in the engine and the dynamo, is very high, it is essential that all bolts and screws be kept tight.

SPEED OF ENGINE AND DYNAMO.

9. Ordinarily, to obtain the proper results from the dynamo, a speed of 1,800 revolutions per minute should be maintained. With some dynamos, however, a speed of 1,900 or 1,950 revolutions per minute may be necessary, this variation being due to differences in the dynamos. To increase the speed of the engine, tighten the screws *117*, Fig. 1, that govern the tension of the springs *41*; to decrease the speed, slacken the screws. Every half turn of the screws, ordinarily, will increase or decrease speed about 50 revolutions per minute, but care should be taken to change all screws alike.

10. Testing the Governor.—To test the efficiency of the governor, pull out one of the wires that lead from the dynamo to the lamp. If the speed increases to 2,500 revolutions or over, it indicates that the plunger valves *38* are cut and need refacing, so as to make a new and tight seat. This test should be made monthly to prevent the valves wearing to a condition that will admit of such high speed as to cause the fracture of the moving parts by centrifugal force. When engines are first put into service, particles of scale or molder's sand, which it is impossible to entirely remove, work in and cause the valves *38* to stick, interfering with the functions of the governor; the

upper valve suffers most from obstructions of this nature. To overcome this trouble, it is advisable, after running the engine 2 or 3 hours when first set up, to take off the cap *3*, Fig. 1, and remove any dirt, scale, or sand that may have accumulated. If this is repeated on completion of first two or three trips, all danger from this source will be eliminated and no further trouble will result.

TAKING UP LATERAL MOTION IN SHAFT.

11. When the amount of end play or lateral movement of the main shaft exceeds $\frac{1}{32}$ inch, it should be taken up as follows: Slack the screws in the thrust piece *8* and then, looking lengthwise of the shaft and toward dynamo end of machine, tap the top part of the thrust piece toward the right until the end motion is sufficiently reduced. The proper amount of end thrust when the engine is warm and in working order is about $\frac{1}{16}$ inch.

CARE OF THE DYNAMO.

12. When the dynamo is working properly, no sparks should be seen at the brushes. The upper brush is made of graphite, the lower one, shown at *B*, Fig. 4, is of carbon, and, when necessary to remove these brushes for any cause, they can be taken out without disturbing the tension of the springs *113*. The tension of this spring, adjusted by the thumb nut *110*, should be just sufficient to hold the brush in such contact with the commutator as will prevent sparking; too much tension will result in undue wear and heating of the brushes and commutator. Ordinarily, the spring *113* will have the proper tension when the end supporting the brush will rise from $\frac{3}{16}$ to $\frac{1}{4}$ inch if relieved. This adjustment should be looked after daily, depending on the hardness of the brushes. The brushes should fit the commutator perfectly; if the fit is poor, or if the brushes do not make good contact with the commutator, they will spark badly. To fit new brushes to the commutator, take a strip of No. 0 sandpaper about $1\frac{1}{2}$ inches wide, slip it between the commutator and brush with its rough side toward the brush,

and then move it to and fro, as shown in Fig. 5, until the brush has been ground to a proper curvature.

If you find the commutator is running dark and has the appearance of being rough, it should be cleaned. To clean it properly, remove the brushes, tack a piece of No. 0 sandpaper

FIG. 5.

on a board of the proper size, start the dynamo running and then work the sandpapered board as you would a file, holding it level on the moving commutator. Do not attempt to just use the paper itself or to hold the paper with the fingers, as this treatment will probably do more harm than good. Crocus cloth may be substituted for No. 0 sandpaper, but in no case must emery cloth or a file be used. If the commutator becomes very rough or out of true, it should be trued up in a lathe, using a sharp tool and taking very light cuts.

After turning a commutator down, polish it with sandpaper. After truing or cleaning a commutator, care should be taken to see that the sections of the commutator are not connected by a burr or a piece of metal reaching across the strips of mica that separate the sections. The mica should be kept just a trifle below the surface. If allowed to project slightly, it will cause the brushes to vibrate so as to produce sparking. A common three-cornered file, ground to a proper point, makes a good tool to use in keeping mica strips down. However, care should be used in handling it, for, if the mica is cut too low, the groove will collect dirt and cause a short circuit. Great care should be taken to leave no points or ragged edges that will cut away the brushes. Do not lose sight of the fact that the commutator is the vital part of the apparatus and requires care and attention. A daily cleaning, using a small piece of damp waste and rubbing lengthwise of grooves, afterwards finishing with dry waste, will remove dust from grooves and keep apparatus in good condition, and makes the smoothing up of the commutator unnecessary except at long intervals. In passing from the dynamo to the lamp, it is well to remember that ice, water, oil, and dirt are enemies of all electrical apparatus. Electricity will always take the easiest path, and foreign matter always stands ready to point the way. Keeping this in mind, the necessity of maintaining an uncompromising warfare on dirt should be apparent.

DESCRIPTION AND OPERATION OF LAMP.

LAMP CONNECTIONS.

13. The lamp used is of the arc type; it is self-adjusting, and, if properly cared for and a clean reflector is used, gives an intensely brilliant light. The wires used to convey the current from the dynamo to the lamp connect with the binding posts *28* and *29* in the lower brush holder, Figs. 3 and 5, and lead to similar binding posts on the lamp. Unless the binding posts are removed and their positions changed, it is impossible

to misplace the wires, since the size of the wire connections and the holes in the binding posts are not alike. If the lamp burns with a peculiar green hue, throwing little or no light, the current is reversed, passing through the lamp the wrong way. This may happen by reason of binding posts being removed and having their positions changed in replacing. At other times, the dynamo may reverse its current without apparent cause. This occurs but seldom and is caused by some radical changes brought about by exposure to strong magnetic influences. When the current is reversed through the lamp, the trouble can be readily overcome by reversing the position of the binding posts *28* and *29* in the lower brush holder, Fig. 3, putting post *28* in place of post *29*, and vice versa, taking care not to disturb the fibrous insulation under the posts.

TRIMMING THE LAMP.

14. Before starting the lamp, see that the point of the lower copper electrode *109*, Fig. 6, is clean and free from scale; this scale is formed when the lamp is idle, and should be removed with a file, maintaining an angle of about 45°, with a point $\frac{1}{8}$ inch in diameter. When this scale is allowed to accumulate, it acts as a non-conductor and prevents the current from passing through, and no light can be had until it is removed. If the copper electrode burns or melts off at the upper end, the equipment is running too fast and the speed should be promptly reduced. When satisfied with the condition of electrode *109*, a carbon should be put in by removing the carbon holders *87* and *88* from the guide *100*. After securing the carbon in the holder, grasp it by the thumb and forefinger, with the remaining fingers resting on guide *100*; then it can readily be put in place. With a little practice, the lamp can be trimmed in a very few moments, and in the dark if necessary. After putting in a new carbon, always push down on lever *90*, Fig. 6, and notice if the carbon lifts and falls freely. If it does not lift, it is not in proper place in the clutch *44*; if it does not fall down freely, turn it around until a free movement is secured. A carbon should burn 8 or 9 hours. Before

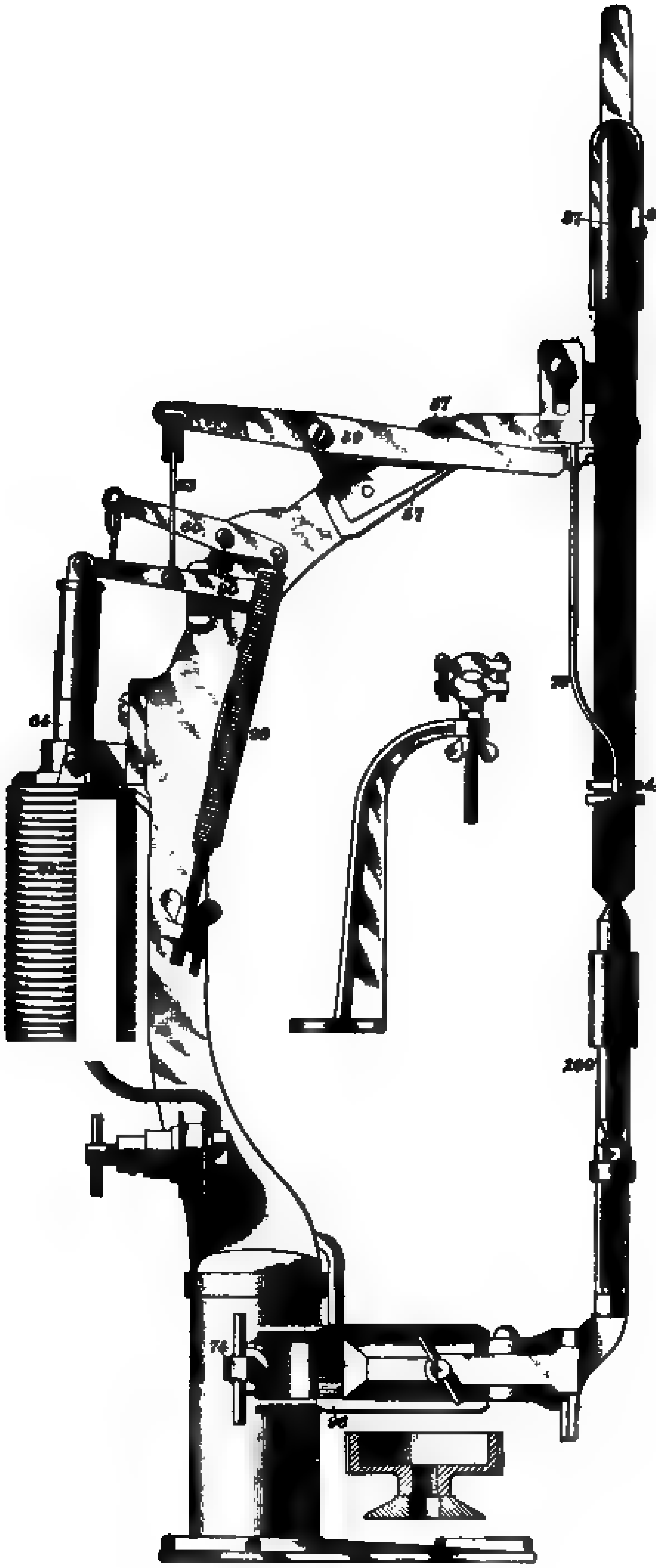


Fig. 6.

putting it into the lamp, examine it to see that it is smooth and free from cracks. The best carbons are none too good for this service.

REGULATING THE LAMP.

15. The tension spring *93*, Fig. 6, serves two purposes: *First*, it brings together the points of the carbons so as to establish the arc when the dynamo is set in motion, a complete circuit being necessary to establish a current; if the carbons are separated but a fraction of an inch, the lamp will refuse to work, the current refusing to jump across the separation. The presence of oxidation or scale on the electrode, as previously mentioned, will cause this separation of the carbons, though, to all appearances, an actual contact exists. *Second*, with the lamp properly trimmed, steam turned on, and the dynamo set in motion, the spring *93* performs its second function.

As the current enters the lamp and passes through the solenoid *65*, the iron magnet *64* is drawn down, thus providing, through the medium of the lever *90* and lever *59*, for the necessary separation of the carbons. The spring *93* is connected to the end of lever *60* and exerts a force in the opposite direction to that of the solenoid. When this spring is properly adjusted, it prevents the solenoid pulling the carbons too far apart. If it is too strong, the magnet will be unable to pull the carbons apart and no light will be produced. If the dynamo is run long in this condition, the heat generated by the current will be sufficient to burn out the armature or field wires of the dynamo. If the spring is too weak, the lamp will alternately flash and then go out, on account of the magnet *64* being drawn down too far. When the light goes out, the current is broken and thus destroys the strength of the solenoid *65*, and the weak spring will draw down the carbon for a moment, reestablishing the current only to go out again. The spring should be adjusted to admit of the lamp flickering a little when the locomotive is standing; it will then be in shape to insure the maximum amount of light when the engine is running, and the light will burn steadily at that time. If the light dies down when the locomotive is running very fast, the spring *93* may be a trifle too tight. This trouble

may be overcome by slacking the tension slightly. In some cases, however, the clutch spring *92* may be too loose, allowing the back edge of the clutch *44* to be jarred up, thus releasing the carbon. To sum up the adjustment of the spring *93*, remember that the volume of light will depend to a great extent on the way you regulate the tension of this spring. A good rule is to adjust it as loose as possible and not have the light go out when the locomotive is stationary. To determine whether a failure exists in the dynamo or the light, test it by laying a carbon across both binding posts on the dynamo; if a flash occurs when it is removed, the trouble is in the lamp.

16. Adjusting the Clutch.—If the carbon feeds too fast, the clutch rod *78*, Fig. 6, should be adjusted to take up the lost motion or the excessive travel that prevents the clutch *44* from gripping the carbon properly. Sometimes this trouble can be overcome by removing the cotter pin in the carbon holder *100*, taking the spring out of the casing and stretching it to give it more set. By shortening the wire link *63*, the magnet *64* is held farther out of the solenoid *65*, thus giving the clutch a greater movement and causing it to clutch the carbon more firmly, which will prevent the jar of the locomotive, when on rough track, from shaking the carbon through the clutch faster than it burns. If this wire is made too short, however, the lamp will jump badly.

FOCUSING THE LAMP.

17. The lamp can be moved in all directions for focusing. The vertical focus regulates the distance at which the light will strike the track in advance of the locomotive. To get the proper vertical focus, loosen the setscrew *74*, Fig. 6, and move the lamp up or down by changing the adjusting screw *98*. To make the light strike closer to the engine, raise the lamp; to make it strike farther away, lower the lamp. To move it sidewise, backwards, or forwards, loosen the hand nuts above the foot-piece, placing the lamp in the proper position, and tighten them up in place. The light should leave the reflector in parallel lines, and, to secure this result, the point of the

copper electrode must be as near the center of the reflector as possible, also, place the lamp so that the carbon will be directly under the center of the chimney hole. The back of the reflector is supported by an adjustable step for purposes of regulation. If any shadows are cast on the track, the lamp is not focused properly, and, if in focus and the light does not strike the track as desired, move the headlight case on the baseboard. A very small movement will produce marked changes, a movement of $\frac{1}{8}$ inch changing the position of the light several feet on the track.

SHORT CIRCUITS.

18. Care must be taken to avoid short circuits. These are most liable to occur (1) in the washers under the binding posts *28* and *29* of the dynamo, Fig. 3; (2) in the fiber *96* of the lower arm, or the fiber *57* of the upper arm, Fig. 6, of the lamp; and (3) in the insulation on the main wires, cab wires, etc. When laboring against a short circuit, though a heavy current will be generated, a weak light will be produced. If the wires leading from the small screws in the brush holders to the incandescent light in the cab come together, a short circuit may result and the light will go out. In that event, disconnect one of the small wires and look for the cause of trouble at your leisure. If the carbon holder is pushed too far ahead and comes in contact with the reflector, a short circuit will result.

PRECAUTIONS TO BE OBSERVED.

19. As before urged, scrupulous cleanliness will prove the greater factor toward securing a perfect light. Engineers should give the headlight their personal attention for a few moments each day. When engines are pooled, some competent person should have the care of the lights. Reflectors should be cleaned the same as with oil lights. Carbons should be kept in a dry place and prevented from jarring around in boxes, causing fractures that lead to road failures. As all light generates heat, the trouble experienced by the cracking of the glass in the headlight case has been met by moving this glass 5 or

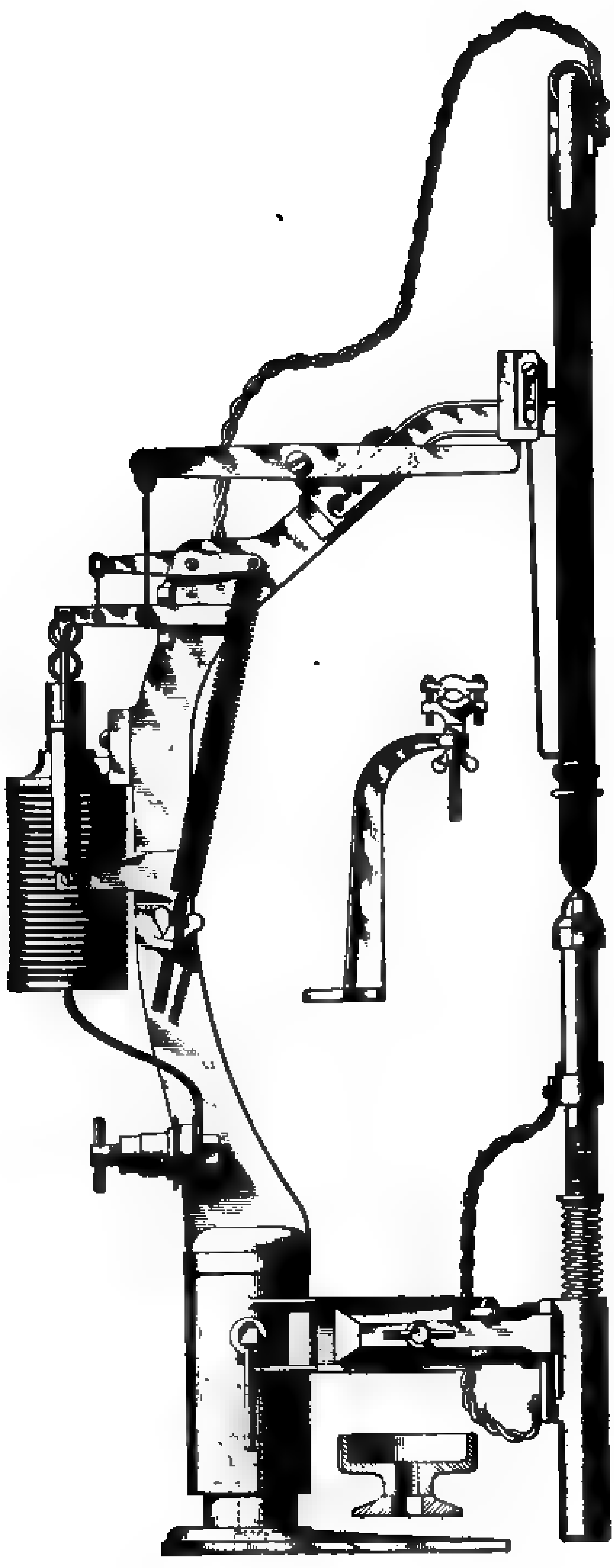


Fig. 7.

6 inches forwards of the usual position. Cutting the glass in two sections has also been practiced and an oval or bent glass will last indefinitely. Do not attempt to remove the reflector from the case until the wires have been disconnected and the top carbon holder *100* has been removed by loosening the thumb nut *79*, Fig. 6. Another style of lamp is shown in Fig. 7, but the foregoing directions apply equally to both styles.

INCANDESCENT LIGHTS.

20. A small number of locomotives have been equipped with a special incandescent circuit used to illuminate the running gear, etc. Where such an arrangement is made use of, a 16-candlepower incandescent lamp is placed inside of the reflector with the arc lamp. By means of a suitable switch, the arc light can be cut out and the incandescent lamps cut in, thus making it easier for opposing trains to approach, with the additional advantage of lighting up the exterior of the locomotive and materially assisting in case of breakdowns, etc. This circuit must be such as will offer the same resistance as the arc light. The switch is placed in the cab at some point convenient to the engineer.

THE NEW YORK AIR BRAKE.

(PART 1.)

QUICK-ACTION AUTOMATIC BRAKE.

GENERAL ARRANGEMENT OF APPARATUS.

THE ESSENTIAL PARTS.

1. The essential parts of the **New York quick-action automatic brake** and their arrangement on the engine, tender, and passenger car are shown in Fig. 1. The **duplex air pump** is usually placed above the running board on either the right or left side of the engine, as convenience requires, and so placed as not to obstruct the view of the engineman. It consists of four cylinders—two combined steam and two combined air cylinders. It will be observed from the figure that the air cylinders are placed above the steam cylinders, *1* and *2* being the air cylinders and *3* and *4* the steam cylinders. To either piston rod there are two pistons attached, one on the air end and one on the steam end. By this arrangement, each air piston moves up and down in its cylinder at the same time that its steam piston does, and, in this way, takes in the air from the surrounding atmosphere and compresses it for use in the brake system.

When the compressed air is discharged from the pump, it enters the discharge pipe *5* and is conducted to the main reservoir; from the main reservoir it is conducted back through the return pipe *6* to the engineer's brake valve, and, when the handle of this valve is in the proper position, it passes through

the valve into the train pipe, from the train pipe it passes to the triple valves and through the triple valves to the auxiliary reservoirs, where it is stored for use in applying the brakes.

2. The standard pressure carried in the train pipe and auxiliary reservoirs is 70 pounds. The main reservoir, which holds the air to release brakes and recharge the auxiliaries, is usually charged up to 90 pounds.

3. The **pump governor** *7* is connected to the steam pipe leading to the pump between the lubricator and pump. Its function is to automatically stop the pump when the desired pressure is obtained, and to start it whenever the pressure falls below the amount required.

4. The **main reservoir** can be placed in any convenient place about the engine, but is generally placed back of the cylinder saddles. It is the receptacle in which a large volume of air is stored for use in releasing the brakes and recharging the train pipe and auxiliary reservoirs. Train-pipe leaks are also supplied from the main reservoir when brakes are released. On heavy mountain grades, when handling long trains, the pressure carried in this reservoir is often greater than 90 pounds.

5. The **engineer's brake valve** is located in the cab, in a convenient position for operating. Its duty is to regulate the flow of air from the main reservoir into the train pipe, and to charge up, and exhaust the air from, the small **supplementary reservoir** *8* usually attached to the roof of the cab; also to control the flow of air from the train pipe to the atmosphere when applying brakes, and to admit it to the train pipe when releasing brakes or to prevent the flow of air in any direction through it.

6. The **air gauge** is placed in the cab in a position to be easily read by the engineer. It is of the duplex type, and is practically two gauges combined. It has two hands or indicators, one colored red and the other black. The *red* hand

indicates the main-reservoir pressure; the *black* hand indicates the train-pipe pressure. The two hands move independently of each other.

7. A **cut-out cock** *9* is placed in the train pipe just below the brake valve. This allows the brake valve to be cut out from the train pipe for the purpose of testing; or, when double-heading, to place the control of all brakes in the hands of one engineer.

8. The **train pipe** is the pipe that connects to the brake valve and reaches back through the whole train. It is connected to the triple valves by means of branch, or cross-over, pipes. After the air passes into the train pipe from the brake valve, it is conducted to the triple valves through the train pipe, and through the triple valves to the auxiliary reservoirs. The pressure carried in the train pipe is 70 pounds, an exception being made occasionally on heavy grades, when the pressure is somewhat increased. The sections of train pipe under adjacent cars are connected by flexible hose and air-tight couplings. Combined drain cups and pipe strainers are placed in the train pipe on all cars, engines, and tenders at the junction of the branch pipe and train pipe. In each drain cup there is a strainer to prevent dirt and foreign matter from getting into the triple valve.

Angle cocks *10*, Fig. 1, for the purpose of closing the train pipe, are placed one at each end of the train pipe on a car—in case it is desired to uncouple the hose for any purpose; also to close the rear end of the train pipe. Angle cocks are open when the handle is parallel with the train pipe, as shown in Fig. 1, and closed when at right angles to it.

The handle of the **cut-out cock** *11*, Fig. 1, is at right angles to the branch pipe when open, and parallel with it when closed. Whenever in doubt as to whether an angle cock or cut-out cock is open or closed, look at the crease in the top of the plug valve. This crease should be parallel with the pipe when the cock is open. If the brake is defective on any car, it may be cut out, without affecting the brakes on any of the other cars in the train, by closing cut-out cock *11*.

9. Each engine, tender, and car should have an **auxiliary reservoir** attached. Formerly, it was customary to use one auxiliary for both engine and tender, but that is not considered good practice now; it is good practice, however, to use one auxiliary for the driver brake and one for the engine-truck brake when the engine is equipped with the latter.

The duty of the auxiliary reservoir is to hold the supply of air that is to be used in applying the brake on the car on which it is placed. The pressure carried in the auxiliary reservoir, when fully charged, is the same as that in the train pipe.

10. A **brake cylinder**, in which there is a piston and rod, is placed under each car of the train. The brake levers are connected to the crosshead *12*, Fig. 1, in such a way that when air pressure is admitted to the brake cylinder and forces the piston out, the brake shoes are forced against the wheels.

11. The **triple valve** is connected at the junction of the train pipe, auxiliary reservoir, and brake cylinder, and has three duties to perform: (1) to charge the auxiliary, by opening a passage from the train pipe; (2) to open a passage from the auxiliary to the brake cylinder, so that the brake may be applied; (3) to open a passage from the brake cylinder to the atmosphere, so that the brake may be released.

12. The **conductor's valve** is placed on passenger, mail, baggage, express, and caboose cars, and is usually located at the end of the car. It is connected to the train pipe by a branch pipe, and is intended for the use of trainmen in emergencies of which the engineer may be ignorant. A cord is attached to the handle of this valve. When this cord is pulled, it opens the valve, and allows air to escape from the train pipe, thus applying the brakes.

MAIN RESERVOIR.

13. The **main reservoir**, Fig. 1, is an air-tight cylinder having a pipe connection with the pump and also with the brake valve. Although the main reservoirs should be as large as the space for them on engines will permit, the following sizes are most commonly used:

STANDARD SIZES OF MAIN RESERVOIR.

Outside Dimensions.		Capacity. Cubic Inches.
Diameter. Inches.	Length. Inches.	
26½	34	15,800
24½	41	17,500
26½	41	20,000
16	126	24,000
18	100	24,000
20½	84	25,000
26½	96	50,000

Main reservoirs vary in size according to the kind of service —freight or passenger—in which the engine is employed. In the best practice, a main reservoir of not less than 16,000 cubic inches for passenger, and from 20,000 to 50,000 cubic inches for freight, service is used, dependent on the number of air-brake cars usually handled in a train.

LOCATION OF MAIN RESERVOIR.

14. The main reservoir is usually located between the frames, back of the cylinder saddle. This is the most approved location, although it is sometimes found advisable to sacrifice the location in order to use a main reservoir of the desired capacity. It should, if possible, be located at the lowest point in the brake system on the engine, in order that all dirt, oil, and moisture may settle there. Then it can, and should be, drained after each trip, a *drain cock* being provided in the bottom of the reservoir for this purpose. The drain cock supplied with the New York main reservoir automatically opens when the main-reservoir pressure is let out at the end of the run. When water is allowed to accumulate in the main reservoir, it not only reduces the space available for storing air, but it works back into the brake system and sometimes carries dirt and oil with it, which gums up the brake-valve ports and prevents the valve from working properly. There is also danger, in winter, of the water freezing and stopping up the pipes. The water that

gets into the brake system is drawn into the air end of the pump with the air. This is especially true on damp and rainy days. The main reservoir is sometimes located between the frames under the deck, sometimes on top and at the back of the tender, and, frequently, under the cab foot-board or under the running boards. When placed in this latter position, two reservoirs that are connected together are generally used. Also, the main reservoir is occasionally seen on top of the boiler.

When the main reservoir is located on the tender, it is necessary to run a line of pipe from the pump back to the tender, and a return pipe from the main reservoir to the engineer's valve. This proves rather expensive, especially as dirt and moisture settle in the hose that connect the pipes between the tank and engine, and soon destroys them.

The objections to placing the main reservoir between the frames under the deck are that it is then harder to pipe the engine, and the reservoir is in the way.

15. A larger main reservoir is necessary on freight than on passenger engines: (1) because of the greater number of air cars handled in freight service; (2) because there is a longer train pipe and more auxiliaries to recharge after the brakes are released; and (3) because the greater the volume of air in the main reservoir, the higher the pressure at which the main reservoir and train pipe will equalize, and the easier, therefore, it will be to release brakes.

When a large main-reservoir capacity is necessary, the best practice is to use two reservoirs so connected together that the air has to pass through both on its way from the pump to the engineer's brake valve. This arrangement gives drier and cleaner air than is possible when only one reservoir is used.

It is often found that, when a pump is heating, the trouble will disappear if the capacity of the main reservoir is increased. If the train is long and the main reservoir small, a high pressure must be carried in the latter in order that it may equalize with the train pipe at a sufficiently high pressure to promptly release the brakes and recharge the auxiliaries. When the main reservoir is large, a much lower reservoir pressure can be

carried, and the pump can also store a greater quantity of air while the brakes are released. When, therefore, the main reservoir is small, the pump must work both faster (or longer) and against a higher pressure; and either of these tends to cause overheating.

DUPLEX AIR GAUGE.

DESCRIPTION.

16. **A duplex air gauge** that indicates both train-pipe and main-reservoir pressures is located in the engine cab, in a position convenient for the engineer to see.

This gauge, shown in Fig. 2 (*a*) and (*b*), consists really of two gauges combined in one, the same scale serving for both hands. The right-hand gauge, which connects with *T*, operates the black hand. This hand indicates the train-pipe pressure, being connected directly to the train pipe. The other connection *M*, a part of the left-hand gauge, is piped to the main-reservoir connection or brake valve. This hand is colored red, and indicates main-reservoir pressure.

PRINCIPLE OF WORKING.

17. An inside view of the air gauge is shown in Fig. 2 (*b*), in which *A* and *B* are two bent tubes of elliptical shape, as shown at (*d*). The tube *B* is connected to the fitting *T*, and the tube *A* to the fitting *M*. The bottom ends of the tubes are held fast, but the top ends are sealed, and free to move.

The action of the gauge may be thus explained: If a tube of elliptical section is bent as shown at *B*, Fig. 2 (*b*), and then subjected to an internal pressure (of either a gas or a liquid), the force exerted will tend to straighten the tube. This is due to the fact that the force exerted within the tube tends to make it assume the circular form shown at (*c*). In assuming the circular form, the concave side *a*, see (*d*), of the bent tube tends to lengthen, while the convex side *b* tends to shorten. These combined efforts tend to straighten the tube out, and therefore impart a movement to its free end.

Tube *A* is connected to one end of the lever *kj* by means of

(a)

(b)

Fig. 2.

the link *c*. This lever is pivoted at *e*, and the end *j* has the form of a toothed sector, which meshes with a pinion on the spindle *i*. The spindle *i* carries the red hand, or pointer, of the gauge, and rotates within a hollow spindle *l*, which carries the black hand. Tube *B* is connected by link *b* to the lever *fg* at a point below the fulcrum, or pivot, so that the black hand will be turned in the same direction as the red one. The lower end of the lever *fg* has the form of a toothed sector which meshes with a pinion on the hollow spindle *l* and operates the black hand.

OPERATION.

18. Since the main reservoir connects with *M*, air under pressure enters tube *A* and tends to straighten it out. This causes the free end of *A* to move to the left, drawing the link *c* with it, thus moving the toothed sector *j* to the right. As this sector engages with the spindle *i*, the latter is made move clockwise, that is, a motion in the same direction as the hands of a clock. The red hand is also given a similar motion.

Train-pipe pressure acts within the tube *B* to straighten it, and the free end is moved to the right. As the bar *b* is connected *below* the fulcrum of the lever *fg*, the movement of the free end of *B* will cause the toothed sector *g* to move to the right, and turn the black hand clockwise also. The greater the pressure within the tubes, the greater will be the tendency for them to straighten out, and the higher will be the pressure registered by the gauge. The small coiled springs *d* and *h* take up the play, or backlash, in the teeth of the sector and pinion.

PUMP GOVERNOR.

DESCRIPTION.

19. There are two kinds of **pump governors** in use—the ordinary kind and the **duplex.** The duplex has two tops (containing the air valve and regulating spring), and the ordinary governor has one top.

A description of the ordinary governor will suffice for both, as

the top sections in the duplex form are alike and are the same as the single top used on the ordinary governor.

The steam-supply pipe to the pump connects to the governor at *X*, Fig. 3, the connection *Y* being piped to the pump, as shown in Fig. 1. All steam used by the pump must pass through the governor before reaching it. When the desired pressure has been accumulated the governor shuts off steam from the pump; it admits steam again when the pressure falls below the proper amount. As used with the brake valve, the governor is operated by chamber *E** pressure, the pipe connection being made to the union *17* at *Z*, Fig. 3.

20. Referring to Fig. 3, it will be observed that chamber *a* is in direct communication with the pipe connected at *Z*, which leads to chamber *E** pressure. A corrugated brass diaphragm valve *13* controls the passage *b* leading into chamber *c* above the governor piston *4*. A heavy regulating spring *10* bears on top of diaphragm *13* and holds it down on bushing *14*, thus forming a valve. The pressure with which this spring holds diaphragm *13* on its seat is a little less than the pressure in chamber *a* at which the governor is intended to operate. The tension of the spring *10* may be regulated by removing the cap *7*, loosening the locknut *9* (if tension is to be increased), and turning the bolt screw *8* in the proper direction to give the result desired. The governor piston *4* rests on top of the steam-valve stem *25*. Piston *4* is held up in its cylinder by the pressure of steam in chamber *26* pressing on the bottom of valve *25*. The packing ring *24* is made to fit as nearly air-tight as possible, in order to prevent any air from leaking into chamber *d* below the piston. The dotted circles *f* below the piston *4* show the drip opening made through the body of the governor. The object of the drip opening is to prevent the accumulation of any air or steam that might leak by the governor piston *4* or stem *5* of the steam valve, into chamber *d*.

A small port *t* is drilled in the body of the governor just

*Chamber *E* is charged to main-reservoir pressure in full release position, to train pipe pressure in running position, and to 20 pounds less than main reservoir pressure in all other positions of the brake valve.

x

FIG 3

below the seat *27* of the steam valve *25*, to allow sufficient steam to pass to the pump to keep it working slowly, thus keeping it warm and preventing condensation of steam when the pump governor has closed valve *25*. If the pump remains inactive for any length of time after full train-pipe pressure has been attained, steam will condense in the supply pipe. When the pump starts to work, this condensation will be thrown out of the stack and over the jacket of the engine; hence, the necessity of port *t*.

OPERATION.

21. The regulating spring *10*, Fig. 3, is adjusted to withstand a pressure of 70 pounds, acting upwards against diaphragm *13*. When the pump is in operation, the pressure in the train pipe and in chamber *a* of the governor increases until a pressure of 70 pounds is reached. When the pressure in chamber *a* is slightly greater than that at which spring *10* is adjusted, the diaphragm *13* is raised and opens the passage *b*. Air in chamber *a* then passes through passage *b* into chamber *c* above the governor piston *4*, forcing the piston down and thus seating the steam valve *25*. As long as the train-pipe pressure remains at 70 pounds, the diaphragm *13* will be held up, passage *b* will be open, and the pressure in chamber *c* will hold the steam valve *25* to its seat. If the train-pipe pressure falls below 70 pounds, the downward pressure of spring *10* will overcome the upward pressure of the air in chamber *a*, and the diaphragm valve *13* will be forced down until it seats on *14* and closes passage *b*. This cuts off the supply of air to chamber *c*, and the air confined therein will escape to the atmosphere through the relief port *e*, which is drilled through the body of the governor just above piston *4*. Piston *4* being relieved of the pressure above it, is raised by the pressure of the steam under valve *25*, and steam then passes to the pump, as indicated by the arrows. The area of piston *4* is so much greater than that of valve *25* that a pressure of 70 pounds per square inch acting downwards on it enables it to withstand the greater pressure per square inch of the steam acting upwards on valve *25*.

In the operation of the governor, the object of port *e* is to permit the prompt release of air from the top of piston *4*, thus starting the pump promptly, when the pressure in chamber *a* reduces sufficiently to allow diaphragm valve *13* to seat and close passage *b*. Although port *e* is rather small, it will, in about 2 seconds, release sufficient air from chamber *c* to allow piston *4* to rise, open the steam port in the governor, and start the pump working again.

DUPLEX AIR PUMP.

22. Fig. 4 shows a longitudinal section through the New York **duplex pump.** Different sizes, such as No. 1, No. 2, etc., are used, depending on the class of service and the amount of air required; but as all sizes are the same in construction and principle, a description of one size will suffice for all.

STEAM CYLINDERS AND HEAD.

23. Referring to Fig. 4, two **steam cylinders** *3* and *4* of equal diameter will be seen, each having a steam-tight piston in it, piston *21* being in cylinder *3* and piston *22* in cylinder *4*. The piston rods *18* extend into the air cylinders *1* and *2* and have the air pistons *31* and *32* attached to them.

A portion of the steam end of piston rods *18* is cut away so as to show the internal construction. The steam ends of these rods are hollowed out for about half their length, to receive the tappet rods *7* and *8*. As the pistons move up and down in the cylinders, just as they are about to complete their stroke, they alternately pull and push the tappet rods, and these in turn move the slide valves *5* and *6*, attached to their lower ends, so as to reverse the motion of the pistons. The slide valve *6* in the head of cylinder *3* controls the admission and exhaust of steam for cylinder *4*, and slide valve *5* performs the same duty for cylinder *3*. These tappet rods, usually called **reversing-valve rods,** have a button head *u* formed on one end. As the piston is approaching the end of its upward stroke, the **reversing-valve plate** *20*, which is attached to the piston

head by bolts *55*, engages this button head *u* and moves the reversing-valve rod a distance equal to the travel of slide valves *5* and *6*. On the downward stroke of the piston, the reversing-valve plate *20* strikes on a shoulder *E* formed on the tappet rod, and moves the valve in the opposite direction a distance equal to its travel. The tappet rods *7* and *8*, the slide valves *5* and *6*, and plates *20* constitute the reversing gear for the pump.

24. Steam is admitted through the connection at *X* and exhausted through the connection at *Y*. The dotted lines *19* show the steam passage from connection *X* through the pump head to the reversing-slide valve chambers *A* and *B*, and the dotted lines from connection *Y* show, similarly, the passage of the exhaust steam from underneath the valves to the exhaust connection *Y*. The steam ports *26* and *28* lead from the steam chest in the head of cylinder *4* to the cylinder *3*; the steam ports *23* and *27* lead from the steam chest in the head of cylinder *3* to the cylinder *4*.

Steam piston *21* is shown at the extreme lower end of cylinder *3* after it has completed its downward stroke. The reversing plate *20* has struck the shoulder *E* on the reversing-valve rod, shifting slide valve *6* to its lower position in bushing *17* and uncovering steam port *23*; this brings steam port *27* into communication with exhaust port *C*. Piston *21* remains stationary until piston *22* makes a stroke. In the position shown in the cut, steam is being admitted to the upper side of piston *22* in cylinder *4*, through port *23*, while at the same time the steam confined in cylinder *4* underneath piston *22* is being exhausted to the atmosphere through port *27*, exhaust cavity *f* of slide valve *6*, exhaust port *C*, and the connection at *Y*. When piston *22* is nearing the end of its downward stroke, reversing-valve plate *20* engages the reversing rod *7* at the shoulder *E*, precisely as was done by reversing plate *20* in cylinder *3* on its downward stroke, and shifts slide valve *5* to its extreme lower position. When in this position, slide valve *5* will open steam port *26* to admit steam to cylinder *3* underneath piston *21*; this also opens exhaust port *D* on its seat at the same time, and permits the steam in cylinder *3* above

piston *21* to exhaust to the atmosphere through port *28*, cavity *e* of slide valve *5*, and the passage *D* leading to connection *Y*. In this manner, the steam pistons are moved up and down in their cylinders. Neither piston can move until the other has completed its stroke and shifted the reversing valve.

25. When steam is shut off from the pump by closing the throttle of the air pump, the following is what occurs: If the piston and valves are in the position shown in Fig. 4, the steam beneath piston *22* flows through port *27* and to the atmosphere through exhaust connection *Y*. The steam in cylinder *3*, port *28*, steam chests *A* and *B*, passage *19* and port *23*, expands, and, acting with the weights of the pistons, forces piston *22* downwards, so that both pistons finally come to rest at the bottom of their cylinders. If the steam should be shut off when both pistons were at the top of their cylinders, say when piston *21* was at the top and piston *22* was just completing its upward stroke, both valves *5* and *6* would then be in their top positions. The steam underneath piston *21* would exhaust through port *26*; the steam in cylinder *4* and in the steam chests, ports, and passages would then expand and force piston *21* downwards, shifting valve *6* to the position shown in Fig. 4, and allowing the steam in cylinder *4* to exhaust. The steam then contained in cylinder *3* above the piston, the steam chests, ports, and passages would expand again and force piston *22* down. Hence, when steam is shut off, the pistons always come to rest at the bottom of the cylinders.

26. When starting, steam enters the chambers *A* and *B*; steam passages *23* and *26* are open for the admission of steam, but only piston *21* will be moved upwards, the steam that enters cylinder *4* simply acting to hold piston *22* down. When piston *21* completes its stroke, it will shift slide valve *6* to its upper position and steam will then enter cylinder *4* through port *27*, and underneath piston *22*, moving it upwards. The live steam already in cylinder *4*, above piston *22*, will then exhaust through port *23*, and the pump will proceed to work in the manner already described.

FIG. 4.

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27. Referring to Fig. 4, *57* is the *union nut* for the steam-pipe and pump connection, and *59* is the union nut for the exhaust pipe. A drain cock *54* is screwed into the steam passage *19*; its duty is to afford a means of draining away any condensation that may accumulate. Cap nuts *15* are screwed into the steam head and against bushings *16* and *17* to hold the bushings in their proper positions. The packing rings *33* prevent leakage of steam from one side of the piston to the other. The reversing valve-plate bolts *55* are screwed into the piston and extend through it, their ends being riveted over. The cylinder-head bolts *52* secure the heads to the cylinder. The center-piece *35* forms the upper head for the steam cylinders and the lower head for the air cylinders. The stuffingboxes are composed of the brass bushings *36*, screwed into the air- and steam-cylinder heads, the gland nuts *37*, and, inside of them, the glands *38*, which holds the packing tightly about the piston rods, preventing leakage of either steam or air. The hole drilled lengthwise at the lower ends of the reversing rods *7* and *8*, and extending up into the cylinder through an opening made sidewise through the rod, is for the purpose of balancing the pressure on each end of the rod by connecting the chamber in the cap nut *15* with the cylinder.

AIR CYLINDERS.

DESCRIPTION.

28. Referring again to Fig. 4, it will be seen that there are two air cylinders *1* and *2* of unequal diameter, the capacity of cylinder *2* being double that of cylinder *1*. Two air pistons *31* and *32* are attached to the piston rods *18*. The rods are attached to the pistons by the locknuts *74*. The brass bushings *39*, *40*, *41*, *42* have cone seats formed on them for the air-inlet or receiving valves *9* and *10*, which admit air to cylinder *2*; *11* and *12* (and also *9* and *10*) are the air-inlet valves for cylinder *1*, and also act as discharge valves for the air compressed in cylinder *2*. The valves *13* and *14* allow the air to

discharge from cylinder *1* into the pipe leading to the main reservoir, and *45* and *46* are the bushings on which their seats are formed. A cap nut *44* screws into the top head directly over valve *13*, to prevent the valve from lifting too high, while the stop *s*, cast in the passage *H*, performs the same duty for valve *14*. Passages *H* and *Z* lead to the discharge pipe; all the air compressed by the pump is forced out through these passages to the main reservoir.

OPERATION.

29. As already explained when describing the action of the steam pistons, each steam piston waits until the other piston completes its stroke before making a return stroke. Since piston *32* is rigidly connected to piston *21* by the piston rod *18*, it makes the first stroke when the pump is started. As piston *32* moves upwards, it compresses the air ahead of it and leaves a vacuum behind it in cylinder *2*, and the pressure of the atmosphere on the outside raises valve *10*, filling the space in the cylinder behind the moving piston with air at atmospheric pressure. When piston *32* has completed its stroke, it waits for piston *31* to make a stroke. As piston *31* moves upwards it compresses the air ahead of it and leaves a vacuum behind it in cylinder *1*; the pressure of the atmosphere raises valves *10* and *12* and the air rushes in behind piston *31* to fill this vacuum. Now both pistons at the extreme upper ends of their cylinders and both air cylinders are filled with air at atmospheric pressure; cylinder *2* (by reason of its greater capacity) has double the volume of air that cylinder *1* contains.

Piston *32* then commences its return stroke, and valve *10* is held on its seat. The air in cylinder *2*, under the piston, is compressed; this raises valve *12* and allows the air in *2* to discharge through port *h*, valve *12* (which now becomes an intermediate discharge valve), and passage *j* into cylinder *1*, underneath piston *31*. At the same time that cylinder *2* is discharging its contents into cylinder *1*, a vacuum is forming behind piston *32* and free air is entering through valve *9* to fill cylinder *2* above the piston. After discharging the air that is

received in cylinder *2* during its upward stroke into cylinder *1*, and, after completing its downward stroke, piston *32* waits for piston *31* to make its downward stroke. The combined contents of cylinders *1* and *2* are contained in cylinder *1* under piston *31*, and as piston *31* commences its downward stroke, valve *12* seats, final discharge valve *14* lifts, and the air is delivered through passage *H* into the pipe leading to the main reservoir.

30. At each stroke made by piston *32*, cylinder *2* is filled with free air from the atmosphere on one side of the piston, and the air in cylinder *2*, on the other side of piston *32* (taken in on the former stroke), is discharged into cylinder *1*. At each stroke made by piston *31*, cylinder *1* is filled with free air from the atmosphere on one side of the piston, and the contents of this cylinder on the other side—consisting of the free air taken in from the atmosphere and the air forced into it by piston *32* from cylinder *2*—are compressed and driven into the main reservoir.

31. There are two sizes of the duplex pump commonly found in service. In the No. 1 size, both steam cylinders and the high-pressure air cylinder are 5 inches in diameter, and the low-pressure air cylinder is 7 inches in diameter. In the No. 2 size, both steam cylinders and the high-pressure air cylinder are 7 inches in diameter, and the low-pressure cylinder is 10 inches in diameter. With the exception of the dimensions, the two sizes are the same in principle and design.

32. Air enters the lower end of cylinder *2*, Fig. 4, through port *h* after lifting valve *10*, and enters the upper end through port *h'* after lifting valve *9*. Air enters the lower end of cylinder *1* from the atmosphere through port *j* after lifting valves *10* and *12*, and enters the upper end from the atmosphere through port *j'* after lifting valves *9* and *11*. The air discharged from cylinder *2* into the lower end of cylinder *1* lifts valve *12*, and passes through ports *h* and *j*. The air discharged from the upper end of cylinder *2* into the upper end of cylinder *1* lifts valve *11* and passes through ports *h'* and *j'*.

Main-reservoir pressure is always present in passage *H* and on the top of final discharge valves *13* and *14*. Hence, before any air can leave cylinder *1*, the pressure in it must be greater than that in the main reservoir and passage *H*. When the air in the lower end of cylinder *1* is compressed to a pressure greater than that in passage *H* and in the main reservoir, it is forced through port *k*, lifts final discharge valve *14*, and passes into the passage *H* and the pipe leading to the main reservoir; the air in the upper end passes through port *k'*, lifts valve *13*, and passes to the main reservoir through passage *H*.

33. Inspection.—All the air valves in the No. 1 and No. 2 pumps have a lift of $\frac{1}{16}$ inch, and may be removed for inspection or repairs by unscrewing cap nuts *44* and *46* and bushings *43* and *39*. To inspect the air pistons, it is necessary to remove cylinder head *47*; to inspect the steam pistons and reversing plates *20*, remove the head *70*.

To inspect reversing slide valves *5* and *6* and reversing rods *7* and *8*, remove cap nuts *15*. Oil cups 53 are provided for the air cylinders.

PLAIN TRIPLE VALVE.

NAMES OF PARTS.

34. An essential part of the automatic air brake is the **triple valve,** of which two kinds are used; the earlier kind is called the **plain triple valve** to distinguish it from the later kind, called the **quick-action triple valve.**

The plain triple valve is used on engines and tenders exclusively. As its name implies, it is a combination of three valves, and is so constructed that, when a reduction in pressure in the train pipe occurs from any cause, all three valves will operate in such a manner as to apply the brakes.

35. Figs. 5 and 6 are sectional views through the body of the plain triple valve, and show the valve in two positions. The names of the various parts, as numbered and lettered in the figures, are as follows: *27* is the triple body; *11* is the

FIG. 5.

FIG. 6.

triple head; *38* is the triple exhaust valve; *48* is the triple graduating valve; *49* is the graduating-valve spring; *40* is the triple-piston valve; *3* is the triple-piston packing ring; *29* is the cap nut for the auxiliary connection; *13* is the drainage plug; *12* is a leather gasket; *26* is one of the nuts on the triple head-bolts; *16* is a nipple for auxiliary connection; *9* is the exhaust-valve spring; *14* is the triple bracket. The space marked *A* is the triple-piston cylinder; *b* is the small feed groove in the wall of triple cylinder; *c* is the space back of the piston, and *m* is a small groove on the shoulder of the triple piston; *E* is the exhaust-valve chamber; *Y* is the opening to the auxiliary reservoir; *f* is a drainage port; *G* is a trap to collect the moisture; *h* is the exhaust cavity in valve *38*; *i* and *j* are exhaust ports in valve seat and bushing *K*; *l* is a service port connecting auxiliary with brake cylinder; *X* is the brake-cylinder connection. The passage *W* leads to the train-pipe connection of the triple valve, and acts as a passage for the air into chamber *A*.

OPERATION.

36. Air enters the triple head at port *W*, marked "*To Train Pipe*," passes through the small grooves *b* in the triple cylinder, and *m* in the shoulder on piston *40* into the chamber *E*, and then passes to the auxiliary reservoir, as indicated by the arrows. Piston *40* is acted on by the air pressure on both sides of it. The pipe leading to the brake cylinder connects at *X*, and the connection to the auxiliary reservoir is made at *Y*. In the tender equipment, Fig. 1, is shown a plain triple valve connected to the auxiliary reservoir, brake cylinder, and train pipe.

37. Chamber *E* is always charged with air at auxiliary-reservoir pressure, and chamber *A* with air at train-pipe pressure, the piston *40* separating one from the other. The piston *40* may be moved to the right or left by increasing or decreasing the pressure in chamber *A* above or below that in chamber *E*. The packing ring *3* is made a good fit in the bushing *R*, so that, when the piston has moved enough to cover groove *b*, air cannot leak by it in either direction.

38. The automatic portion of the mechanism of the plain triple consists of the exhaust valve *38*, graduating valve *48*, piston *40*, and graduating-valve spring *49*. A sectional view of the exhaust valve *38* is given in Fig. 5, and shows the exhaust ports and exhaust cavity. When the piston *40* moves to the position shown in Fig. 6, the graduating valve *48* uncovers port *l*, and auxiliary air can then flow through port *l* and out at *X*, as indicated; but when port *l* is covered, as in Fig. 5, no air can flow to the brake cylinder. The exhaust and graduating valves are surrounded by air at auxiliary-reservoir pressure, which holds the valves to their seats; the springs *9* and *49* are provided for the purpose of holding the valves to their seats when there is no auxiliary-reservoir pressure to perform this duty, thus preventing dirt from collecting on the valve seat and affecting the working of the triple.

Piston *40* controls the movements of both the exhaust valve and the graduating valve. The graduating valve fits snugly between shoulders on the piston stem, while the exhaust valve fits loosely; hence, when the piston moves, it carries both valves with it. The graduating valve being attached, practically speaking, to the piston stem, moves along with piston *40*. The length of the exhaust valve *38* is purposely made less than the distance between the shoulders on the piston stem, so that piston *40*, in moving forwards to service position, will close groove *b*; or, in moving backwards towards release position, will move the graduating valve *48*, and close port *l*, before it moves the exhaust valve *38*. When the exhaust valve is in service position, as in Fig. 6, piston *40* can move to the right or left far enough (about $\frac{1}{4}$ inch) to operate the graduating valve without disturbing the exhaust valve. We thus see that the piston may move a limited distance without moving the exhaust valve; whereas the graduating valve, being secured to the piston stem by the small shoulders *51* and *52*, must move with the piston.

39. When a gradual or service reduction of train-pipe pressure is made, the pressure in chamber *A* is reduced below that in chamber *E*, and auxiliary-reservoir pressure then moves

piston *40* forwards until it touches the leather gasket *12*, as in Fig. 6, which prevents it moving any farther. When a sudden and heavy reduction of train-pipe pressure is made, as in emergencies, piston *40* moves quickly forwards and opens port *l* as before (see Fig. 6). The drainage plug *13* can be removed, when desired, to drain the triple of moisture.

40. The triple valve has three duties to perform: (1) to charge the auxiliary; (2) to apply the brakes; (3) to release the brakes.

When an engine is coupled to a car, air from the main reservoir flows into the train pipe; thence through the branch pipe, as shown in Fig. 1, and enters the triple valve at port *W*, Fig. 5. When the triple is "cut in," the air can flow in at port *W*, and on through grooves *b*, and *m* into chamber *E*, whence it passes into the auxiliary reservoir. If piston *40* were in forward position, as in Fig. 6, the air at train-pipe pressure, on entering chamber *A*, would force piston *40* back to release position, as shown in Fig. 5. The air continues to feed past piston *40* as long as train-pipe pressure in chamber *A* is greater than the auxiliary pressure in chamber *E*. The usual train-pipe pressure is 70 pounds; hence, when the auxiliary pressure has reached 70 pounds, the pressures in chambers *A* and *E* are equal, and the auxiliary is said to be fully charged. That side of piston *40* facing port *W* is generally referred to as the **train-pipe side,** while the other side is generally called the **auxiliary side,** or the **exhaust-valve side.**

41. Time Required to Charge an Auxiliary Reservoir.—A modern triple valve should charge an auxiliary reservoir from 0 up to 70 pounds in about 70 seconds, with a constant train-pipe pressure of 70 pounds. With the triple in release position and the auxiliary reservoir charged, there will be 70 pounds in the train pipe and in the auxiliary reservoir, and no pressure at all in the brake cylinder, since the exhaust-valve cavity *h* then connects the brake cylinder with the atmosphere, the communication being through the ports and passages *j* and *i*.

APPLICATION AND RELEASE OF BRAKES.

42. Applying Brakes.—To apply the brakes, it is necessary for a train-pipe reduction to be made. This may be made (1) in the usual way by the engineer; (2) by the use of the conductor's valve; (3) by a burst hose or a heavy leak in the train pipe, or train parting.

If the engineer makes a reduction of 7 pounds in the train pipe, only 63 pounds will remain in chamber *A*, whereas there will be 70 pounds in chamber *E*, or the auxiliary side of piston *40*. This greater auxiliary pressure will force piston *40* forwards. While being forced forwards, piston *40* first closes the feed groove *b* and moves the graduating valve *48*. The graduating valve, however, cannot uncover port *l* until the exhaust valve is moved to service position. By the time the feed groove *b* is closed by piston *40*, the shoulder *51* of the piston stem strikes the exhaust valve *38* and a further movement of the piston carries valve *38* with it. This movement of the exhaust valve covers port *j* and closes the exhaust cavity *h* to the brake cylinder. When piston *40* touches the leather gasket *12*, Fig. 6, it can move no farther. With the triple piston in this position, the service port *l* in the slide-valve seat is uncovered. The service port being uncovered, there is then direct communication between the auxiliary reservoir and the brake cylinder, and air can flow from the auxiliary reservoir, through the service port *l* and passage *X*, into the brake cylinder, where the pressure will force out the brake piston and set the brakes. So long as the auxiliary-reservoir pressure is greater than that in chamber *A* and the train pipe, piston *40* will be held against gasket *12* and port *l* will remain uncovered; in this position, however, auxiliary-reservoir pressure flows into the brake cylinder through port *l*, gradually reducing auxiliary pressure until, finally, it becomes lower than that in chamber *A* by an amount sufficient to overcome the slight friction of the packing ring *3* and graduating valve *48*, when piston *40* and graduating valve *48* are moved back sufficiently to close port *l*. The pressure of air on the train-pipe side of piston *40* will still be a little greater than that in the

auxiliary reservoir, but not enough greater to overcome the additional friction encountered in moving the exhaust valve *38*; the piston therefore stops as soon as the service port has been covered. This is called the **lap position**; in this position, all ports are *blanked*. The brakes are now *partially* set; a further train-pipe reduction will be necessary to apply them harder.

43. If another 5-pound reduction in the train-pipe pressure is made, there will be a pressure of 58 pounds in the train pipe and 63 in the auxiliary. The greater auxiliary pressure again forces piston *40* to the left; but, in this case, the exhaust valve is already in service position, not having been moved when the graduating valve was placed in lap position, and it is only necessary to move the graduating valve sufficiently to uncover port *l*. The amount port *l* opens depends on the rapidity of the train-pipe reduction. Service port *l* is again uncovered and communication is established between the auxiliary reservoir and the brake cylinder. The auxiliary-reservoir pressure is again reduced and the service port covered automatically by the piston *40*, when the auxiliary-reservoir pressure becomes a little less than that in the train pipe.

44. After the exhaust valve has once been moved to service position, Fig. 6, it remains in that position until the brakes are released. Each reduction of train-pipe pressure causes the brakes to set harder, and these reductions may be continued so long as the pressure in the auxiliary is greater than that in the brake cylinder. When these pressures become equalized, the brake is fully set, and a further train-pipe reduction would be a waste of air. Ordinarily, a 20-pound reduction in the train-pipe pressure will cause a full application of the brakes, since a reduction of this amount will equalize the pressure in the auxiliary reservoir and brake cylinder.

45. Releasing Brakes.—To release brakes, the engineer allows the air in the main reservoir to feed rapidly into the train pipe. When the pressure on the train-pipe side of piston *40* is sufficient to overcome auxiliary pressure and the friction of the working parts, the piston is forced to release position, carrying

the graduating valve and the exhaust valve with it. In this position, see Fig. 5, the feed groove *b* is open, and air from the train pipe feeds through ports *b* and *m* to recharge the auxiliary reservoir. At the same time, the air in the brake cylinder escapes through *X*, and ports *j* and *i* into the atmosphere.

46. Emergency Application.—To apply brakes in an emergency, it is necessary to make a sudden and heavy reduction in the train-pipe pressure. This sudden reduction in pressure causes piston *40* and graduating valve *48* to move to the left very quickly. Air at auxiliary-reservoir pressure then passes into the brake cylinder in the usual manner. The service port is thus fully opened, and the pressure in the auxiliary reservoir and brake cylinder equalizes quickly. The emergency application sets the brakes more quickly, but not with greater force, than the service application.

To get the full value of the emergency action of the brakes it is necessary to make a sudden reduction of 20 pounds or more in train-pipe pressure. After an emergency application, the release of the brakes is accomplished in the same way as previously described in Art. **45**, after a service application.

QUICK-ACTION TRIPLE VALVE.

DESCRIPTION.

47. The **quick-action triple valve** is automatic in its action and can be used on a train, some of the cars of which are fitted with the plain triple valve.

Fig. 1 shows the arrangement, on passenger car, of the quick-action triple, auxiliary reservoir, brake cylinder, and connections. A car drain cup is inserted in the train pipe; a branch pipe extending from this connects with the triple, as shown. In this branch pipe is a stop-cock *11*, by means of which the brake on that particular car can be *cut out* or *cut in*, as desired, without interfering with the brakes on the rest of the train. When the handle of this cock stands at right angles, or crosswise, of the branch pipe, the brake on that car is cut in, that is,

Fig. 8.

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it can be operated from the engine in the ordinary manner. When the handle is turned so as to be parallel to, or in line with the pipe, the brake on that car is cut out, or is inoperative.

Fig. 7 shows the quick-action triple valve connected to the brake cylinder, this illustration being on a larger scale than in Fig. 1. The branch pipe from the car drain cup before mentioned connects with the triple valve at *W*. The opening *d* of the triple valve communicates with the passage *P* in the cylinder head, through which air is conducted to and from the brake cylinder. The opening *Y* connects with a pipe *12* leading to the auxiliary reservoir, through which the air is conducted between the auxiliary reservoir and the triple valve.

48. The parts that compose the quick-action triple valve as lettered and numbered in Fig. 8 are: The triple piston *128*; the exhaust valve *38*; the graduating valve *48*; the packing ring *3* in triple piston; the exhaust-valve spring *9*; the graduating-valve spring *49*; the cylinder extension *c* of piston *128*; the vent-valve piston *129*; the packing ring *45* in piston *129*; the middle section, or flange, *130*, and seat for vent valve; the leather gaskets *133* and *134*; the triple head or cap *126*; the vent valve *71*; the rubber seating *20* on valve *71*; the vent-valve spring *132*; the cap bolt *135*; the stop *142* for piston *129*; the emergency cap *127;* the emergency-cap bolt *136*; the emergency piston *137*; the emergency valve *138*; the rubber seating *20* on valve *138*; the emergency-valve spring *140*; the emergency-cap nut *141*; the non-return check-valve *117*; a drainage plug *32*; the train-pipe connection *W* to triple; the triple strainer *28*. The middle section or flange *130* is now being made of cast iron. The small port *F* drilled through piston head *129* is to supply air from the train pipe to chamber *G* between the two pistons *128* and *129*; *K* is a passage in the triple-valve body to allow air from the auxiliary reservoir to pass to emergency valve *138*; *L* is a chamber in the triple-valve body between valves *138* and *117*; *125* is the drainage part of the triple-valve body. Through chamber *L* air from the auxiliary reservoir passes on its way to the brake cylinder in emergency applications. *M*, Fig. 9, is a

vent port to atmosphere from passage *H*. *J* also is a vent port to the atmosphere, being the two rectangular ports under piston *137*. The feed groove in the triple-valve cylinder is at *b*, while *m* is a feed groove in the shoulder of the triple piston.

OPERATION.

49. Service Application.—The description and mode of action of the service part of the plain triple valve applies also to that of the quick-action triple valve. It will be observed, however, that the piston *128* of the quick-action triple valve is extended so as to form a cylinder in which vent-valve piston *129* is fitted.

In the service application, a gradual reduction in train-pipe pressure is made, and piston *128*, Fig. 8, moves slowly forwards. After piston *128* has moved far enough to close feed groove *b*, exhaust valve *38* is engaged by collar *x* on the piston stem, and, with graduating valve *48*, is moved until the exhaust ports *j* and *i* are closed and service port *l* is opened (see Fig. 9*). The pressure of the air in chamber *G* can reduce as fast as the pressure in the train pipe reduces; the air in the auxiliary reservoir expands slowly into the brake cylinder, and the brake is applied with any degree of force desired up to full application, the same as with a plain triple valve.

To release the brake, the main-reservoir pressure is allowed to feed into the train pipe, thus increasing the pressure in chamber *A* (and in chamber *G* by feeding through the port hole *F*) above that in the auxiliary reservoir and forcing the triple piston, exhaust valve, and graduating valve back to their normal positions. In the release position, Fig. 8, feed grooves *b* and *m* are uncovered, allowing air from the train pipe to pass to the auxiliary reservoir and recharge it. Exhaust ports *j* and *i* are uncovered, and air in the brake cylinder escapes to the atmosphere, thus releasing the brakes.

* Figs. 9 and 10 are conventional drawings of the triple valve shown in Fig. 8, in which all the mechanism of the triple is represented as being in the same plane in order to show more clearly the relations of the different valves and passages.

J

Y

FIG. 9.

Fig. 10.

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50. Emergency Application.—In emergencies, it is very essential that the brakes be applied quickly with full force, and as nearly simultaneously throughout the whole train as possible. The passage *K* leads from the auxiliary reservoir to the small chamber behind emergency valve *138*, and is always filled with air from the auxiliary reservoir.

In making an emergency application, a heavy, quick reduction in the train-pipe pressure is necessary in order to put the quick-acting valves into operation. When a reduction of this kind is made, the air confined in chamber *G*, Fig. 8, between the pistons *129* and *128*, cannot reduce in pressure as fast as the pressure is reducing in the train pipe, on account of the small size of port *F*, and, therefore, piston *128*, in moving forwards, cushions on the air in chamber *G* and drives piston *129* ahead of it. The stem of piston *129* bears against the lever arm *p* of vent valve *71*, and as piston *129* moves forwards, vent valve *71* is forced back from its seat into the position shown in Fig. 10. This allows the train-pipe air to enter passage *H*, which leads around the valve body to piston *137*, and the pressure thus exerted against piston *137* quickly moves it forwards. The stem of piston *137* extends across the valve body so as to almost touch valve *138*; hence, when piston *137* moves forwards, its stem unseats valve *138*. This movement provides a large opening for the auxiliary air to escape to chamber *L*, and from thence past check-valve *117* to the brake cylinder (see Fig. 10), while at the same time the graduating valve *48* uncovers the service port *l*, thus providing another passage into the brake cylinder for the auxiliary air.

51. The duty of the vent valve *71* is to vent train-pipe air to the atmosphere in emergency applications. This air is vented into passage *H*, and, forcing piston *137* forwards, escapes to the atmosphere through ports *J* and *M*. This causes a local reduction in train-pipe pressure at the triple valve, which starts the next triple valve into quick action, and so on throughout the train.

When valve *138* is forced back from its seat by piston *137*, it makes such a large opening for the escape of the auxiliary

air into the brake cylinder that there is an almost instantaneous equalization of pressures between the auxiliary reservoir and the brake cylinder. Hence, in emergencies, the mechanism of the quick-action triple provides for the application of the brakes throughout the train in the shortest time possible, and the full force of the auxiliary-reservoir pressure is available in the brake cylinder.

Fig. 8 shows the triple valve in release position and also gives a view of all emergency valves. The conventional drawing in Fig. 9 shows the quick-action triple valve in the service-application position, and Fig. 10 shows it in the emergency action.

52. Vent valve *71* and piston *129* are moved back to their normal position after the emergency application by the spring *132* and the pressure of the train-pipe air, the pressure of the air in chamber *G* having by this time reduced sufficiently to permit this. When the train-pipe pressure no longer holds piston *137* at the extreme right of its travel, spring *140* pushes valve *138* and piston *137* back to the normal position, and no more air can pass from the auxiliary reservoir into chamber *L*. Spring *118*, Fig. 8, serves to hold check-valve *117* on its seat. The duty of valve *117* is to prevent brake-cylinder air escaping into chamber *L*. The release of all brakes on the train is effected in the same manner as after a service application.

FREIGHT AND PASSENGER EQUIPMENTS.

53. An illustration of the **freight-car equipment** now used is given in Fig. 11. It consists of auxiliary reservoir *10*, brake cylinder *2*, and triple valve *18*. This equipment must be made very compact on account of the limited space for it on freight cars. It appears different from that used on passenger cars, shown in Fig. 7, but it is nevertheless exactly the same in principle and operation.

In the **passenger-car equipment**, Fig. 7, there is a pipe *12* leading from chamber *Y* of the triple valve to the auxiliary reservoir; whereas, in the case of the freight-car equipment, Fig. 11, the air passing from the train pipe into the triple valve goes direct to the auxiliary reservoir.

In the freight equipment, pipe *b*, Fig. 11, connects the triple valve *18* with the brake cylinder, while in the passenger equipment, the triple is attached directly to the cylinder. When the brake is released in a freight equipment, air from the brake cylinder flows through pipe *b* and out through the triple exhaust to the atmosphere.

In the passenger equipment, Fig. 7, the piston rod is fastened to the crosshead *10*, and the brake levers, also connected to the crosshead *10*, are controlled by the cylinder piston, the levers being moved every time the piston moves. In the freight equipment, Fig. 11, a push rod is attached to one end of the piston in the brake cylinder, the outer end (not shown in the figure) being connected to the brake levers. When the handbrakes are applied, the push rod may be drawn out without moving the piston. When the air brake is applied, piston *8* is forced out, carrying the push rod with it.

There are practically no

points of difference in the freight and passenger equipments other than those already described, and a description of the parts in the one will apply equally to those of the other. The various parts of the triple valve have already been described and its mode of working explained.

54. The **auxiliary reservoir** *10*, Fig. 11, is a storage reservoir. The air stored there is for use in the cylinder *2*, and its use is confined entirely to the car on which it is placed.

The release valve *17*, or **bleed cock**, as it is sometimes called, reduces the auxiliary-reservoir pressure when opened; hence, if the brake on any particular car should stick, it can be released by opening the bleed cock of the auxiliary on that car until air begins to exhaust from the triple valve, when the bleed cock should immediately be closed. "Bleeding" the auxiliary reservoir reduces the pressure of the air within it below that in the train pipe; this forces the triple piston to release position and releases the brake.

The brake cylinder is oiled through oil plug *16*. The piston *3* is operated by the air in auxiliary reservoir *10* when applying the brakes. In the top of the brake cylinder will be noticed a small groove *a* called the **leakage groove**; it allows any air that may leak into the brake cylinder when the brakes are applied from a very light reduction to pass by piston *3* and out to the atmosphere. When the brakes are released the exhaust port of the triple takes care of any leakage. The groove has generally been placed in the top of the cylinder, although in many freight cylinders they are now placed in the side, midway between top and bottom. In these positions it is least likely to become clogged with dirt. It is made of such a length that the brake piston must move out about 1½ inches before the groove is covered. Leakage grooves are found in the brake cylinders of freight and passenger cars, and also on most tenders, and in some driver-brake cylinders. When applying the brakes, air enters the cylinder and forces piston *3* out, and the **release spring** *9* is compressed; when releasing the brakes, air leaves the cylinder, and the release spring forces piston *3* back to release position, as

shown in Fig. 11. The front cylinder head *4* acts as a guide for the sleeve *3*.

The cup leather packing *7* keeps the air that enters the cylinder from passing by the piston; it takes the place of the

(a)

(b)

(c)

(c)

Fig. 12.

ordinary iron packing rings used in steam cylinders. As the air enters the cylinder it strikes the flanges of the leather, forcing them against the walls of the cylinder, and forming an

air-tight joint. The follower plate *6* holds the leather packing in place. Air is prevented from passing the piston by the expander ring *8*, which forces out the leather against the walls of the brake cylinder.

TRAIN-PIPE COUPLINGS.

55. In Fig. 12 (*a*) is shown an **air-brake hose** *H* with the nipple *N* and coupling *C* attached; they are fastened to the hose by means of the clamps *c*, *c*. Fig. 12 (*b*) is an enlarged view of the coupling *C* shown in (*a*); this is a device for coupling together the hose on two adjacent cars. Fig. 12 (*d*) is an angle cock, one of which is attached to each end of the train pipe on each car, as seen in Fig. 1. Connection is made between hose and angle cock by means of the hose nipple *N*, see (*a*), which is screwed into the angle cock at *1*, see (*d*), the end *6* of the cock itself being screwed on to the train pipe. The plug valve is operated by the handle *4*; *3* is the liner, or bushing, in which the plug *2* works and constitutes the valve body. As the valve now stands, air can pass through it. To stop the flow of air, the handle must be placed at right angles to the position here shown. The spring *5* holds the plug tight to its seat. In (*b*), *2* is a rubber gasket, by means of which a tight joint is made when the couplings are united between two cars. (*c*) shows what is called a **dummy coupler.** The coupling *C* when not in use is hung in the dummy coupler, itstead of allowing the hose to hang down and collect dirt, snow, and cinders, which would gradually work into the triple valves and impair their action.

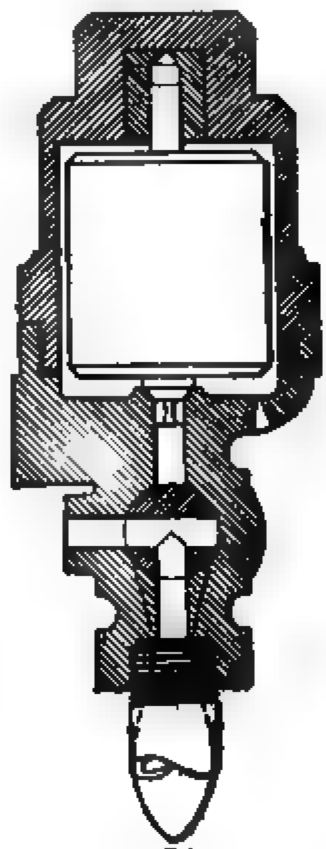
PRESSURE-RETAINING VALVE.

56. The **pressure-retaining valve,** shown in Fig. 13, is used on freight cars in all sections of the country, and on passenger cars, engines, and tenders in mountainous districts.

This valve is located at the end of freight and passenger cars, usually within easy reach of the trainmen, and is connected by a pipe at *X* with the exhaust port of the triple valve.

Its purpose is to retain a pressure of 15 pounds in the brake cylinder, in order to have sufficient braking power to keep the speed of a train from increasing too rapidly while the engineer is recharging the train after a release on a grade, and preparatory to another application of the brakes. The retainer cap *3* acts as a guide, and keeps the weighted valve *4* from falling out. The weight of valve *4* is such that a pressure of

(a)



(b)

FIG. 12.

15 pounds per square inch is required in port *b'* in order to raise the valve. The body of the retaining valve is shown at *2*; *6* is a plug valve operated by the handle *5*.

57. When the retaining valve is cut out, the handle *5* points straight downwards, as in view (*b*). If the brakes are released with the handle *5* in that position, air from the brake cylinder will pass through the exhaust port of the triple valve, through the pipe connecting the triple valve with the retaining valve at *X*, and on through ports *b*, *a*, and *e* to the atmosphere. If, when the brakes are released, the handle *5* is in the position shown in view (*a*), the air coming from the brake cylinder and

entering the retaining valve at *X* will pass through ports *b* and *b'* and so come in contact with the weighted valve *4*. Any pressure above 15 pounds per square inch will raise valve *4* and allow the air to pass out to the atmosphere through port *d*. When the brake-cylinder pressure is reduced to 15 pounds, valve *4* reseats itself and holds the remaining pressure in the cylinder. The diameter of port *d* at the smallest part is $\frac{1}{16}$ inch. This port is made small to further retard the passage of air from the brake cylinder to the atmosphere. The consequence of this is that pressure accumulates in the cap *3*, which acts in concert with the weight of valve *4* to close the valve for a few seconds at frequent intervals until the pressure is reduced to 15 pounds; consequently, the brake-cylinder pressure reduces rather slowly. It takes about 20 seconds for a brake-cylinder pressure of 50 pounds, with average piston travel, to reduce through the retaining valve to 15 pounds, using a modern retaining valve with the small port *d*.

Fig. 14.

In an earlier form of retaining valve, there were two $\frac{1}{4}$-inch holes located similarly to port *d*. These large ports allowed the brake-cylinder pressure to reduce so rapidly that the valve was not sufficiently effective on heavy grades.

Fig. 14 shows the improved retaining valve, which differs from that shown in Fig. 13 in that its plug cock *6* is always held on its seat by the spring *8*. Also, the weighted valve seats on a brass bushing *9*; *7* is the cap for the cock *6*; the arrangement of the ports in the cock is the same as in Fig. 13. The view of this valve is as seen from the front, whereas Fig. 13 is a side

To Train Pipe.

Fig.

view. The action of this valve is the same as that shown in Fig. 13. When the handle *5* is turned down, as in the figure, the valve is cut out; when it stands straight out, that is, horizontally, it is cut in and will retain 15 pounds pressure in the brake cylinder. This retainer has a port similar to port *d* of Fig. 13, although it does not show in this view owing to the manner in which the section is taken.

The retaining valve has nothing to do with applying the brakes; it simply retains a certain amount of pressure in the brake cylinder while the triple valve is in release position.

ENGINEER'S BRAKE VALVE.

DESCRIPTION.

58. The **engineer's brake valve** is that part of the air-brake equipment by means of which the engineer can control the action of the brakes.

The style of brake valve used with the New York air-brake equipment, and the way in which the various pipe connections are made, are shown in Fig. 15.

Pipe *T* is the **return, or main-reservoir, pipe**; it carries the air from the main reservoir to the brake valve and delivers it into the chamber *B* in which the main slide valve *114* is located. This chamber therefore has air at main-reservoir pressure in it at all times, which surrounds and presses down on the top of main slide valve *114*. Pipe *U* is the train pipe through which the air is carried to the triple valves and auxiliary reservoirs. Suitable ports in the seat of slide valve *114* afford openings for the air to feed into the train-pipe chamber *A* of the brake valve, when the handle *123* is in either the *running* or the *release* position. These are the only positions in which the handle can be placed to admit air to the train pipe; in all other positions, the communication between the main-reservoir chamber *B* and the train-pipe chamber *A* is cut off. Chamber *A* is really a cylinder, and has a piston *104* fitted in it, whose stem slides back and forth in the guide *P*, which keeps the piston central in the cylinder during the entire stroke.

One end of the lever *112* is connected to the piston stem *O* by a pin *Q*, and the other end to small cut-off valve *110* by the pin *Q'*. The ends of the lever are forked, so that when the lever *112* turns on its pin *113*, the sides of the forks can slide on the pins *Q* and *Q'* without cramping piston *104* or cut-off valve *110*. The duty of piston *104* is to move forwards in a service application, and, by means of lever *112*, move cut-off valve *110* backwards to lap the service port in the face of slide valve *114*. How this is done will be explained later.

The space or chamber *D* between piston *104* and the cylinder head *102* is filled with air from the train pipe, as is also the **supplementary reservoir** *155*, which communicates with chamber *D* by means of the pipe connection *V*, when the handle of the brake valve is in the running position. The pressure carried in chamber *D* and reservoir *155* is equal to that in the train pipe. The opening *C* in the valve body permits the air to exhaust from the train pipe to the atmosphere when valve *114* is in position for either service or emergency applications. The oil plugs *96* are screwed into the cover of the brake valve, and may be removed before starting the pump, for the purpose of dropping a little oil on the seat of valve *114* to lubricate it and make handle *123* work easily.

59. Figs. 16, 17, and 18 are external views of the rear end and the two sides, respectively, of the engineer's brake valve. The projection *W* and nut *98* enclose the **excess-pressure valve** *97*, shown in Fig. 19.

Fig. 19 is a cross-section (rear view) taken through the feed-valve on the line *a*, *b*, Fig. 23. The cap nut *98* is made long and hollow to receive excess-pressure spring *90*. The feed-valve is made very much like a steam pop safety valve, and has a projection on it to increase the area or surface for the air to press against when it is raised from its seat. The effect of this increase of area is to cause the valve to lift higher, and thus supply the train pipe faster.

Fig. 20 is a section through the side, showing the travel of slide valve *114* and the way in which cut-off valve *110* is controlled by piston *104* and lever *112*.

To Main Reservoir *To Train Pipe*

FIG. 16.

To Train Pipe.

FIG. 17.

To Main Reservoir

FIG. 18.

Fig. 21 is a cross-section through the brake valve on the line *e f*, Fig. 23, and is a front view.

Fig. 22 is a cross-section taken on the line *c d*, Fig. 23.

Fig. 23 shows the valve seat and the arrangement of the ports.

Fig. 24 shows the face of main slide valve *114*.

Fig. 25 shows the small supplementary reservoir.

60. Referring to Figs. 17 and 18, we have the positions of the handles (five in all) shown on the quadrant *124*. When the handle is in the position marked "*Full Release*," the slide valve *114* is at the extreme forward point of its travel, and chamber *B*, containing air at main-reservoir pressure, is placed in full and direct communication with chamber *A* and the train pipe, as shown in Fig. 26. While in this position, air at main-reservoir pressure feeds into the train pipe freely, and quickly raises the train-pipe pressure. Also, chamber *D* and the supplementary reservoir are relieved of all pressure, as they are open to the atmosphere through port *H*, cavity *J* of the slide valve, and the exhaust passage *C*. The port *A*, Fig. 23, in the seat of slide valve *114*, through which the air at main-reservoir pressure passes into the train pipe (while the handle is in full-release position), is purposely made large, so that the air can go from the main reservoir into the train pipe with considerable energy, and insure moving all the triple valves to the release position.

61. Moving the handle to the *running position*, Fig. 27, pulls slide valve *114* back far enough to close the direct-communication port *A*, Fig. 23, and open up an indirect communication with the train pipe by way of the excess-pressure valve *97*, ports *E*, *E*, Figs. 19 and 20, and port *A*, Fig. 23, in the seat of valve *114*, and cavities *M*, *M*, Fig. 24, in the face of valve *114*. The direct communication between the main reservoir and the train pipe being closed, and handle *123* in running position, air must first raise the excess-pressure valve *97* against the tension of spring *90*, which holds it to its seat. The tension of this spring is usually sufficient to resist a pressure of 20 pounds to the square inch pressing on the under side of the excess-pressure valve. As soon as the tension of spring *90* is overcome,

valve *97* lifts from its seat, and air feeds into the train pipe through ports *E*, *E*, Figs. 19 and 20, and port *A*, Fig. 23, and cavities *M*, *M*, Fig. 24. Also, in running position, cavity *J* of the slide valve connects port *H*, which leads into chamber *D*, with chamber *A*, so that train-pipe air flows into and charges both chamber *D* and the supplementary reservoir. A small pin *x* screwed into the quadrant, Figs. 16 and 17, indicates running position.

In the brake valves furnished prior to the No. 413 valve, if the valve handle was left in a certain position between full-release and running position, some of the ports that should not be would be blanked, and it was to do away with that blank position that port *N*, Fig. 24, was made in the face of the slide valve. Some of the old valves had a warning port to warn the engineer when the brake valve was in this blank position.

62. The third position for the handle is the *lap position*, in which all ports except port *H* are blanked, Fig. 23. When in this position, all communication between the main reservoir and the train pipe, and between the train pipe and atmosphere, is closed; port *H*, however, which is wide open in running position, is still open to the train pipe a slight amount in lap position.

63. The fourth position is the *service stop*, and this position is subdivided into five graduated positions. In making all ordinary stops, the handle of the brake valve is operated in the service position, and the number of subdivisions to be used will depend on how much of a reduction in train-pipe pressure is required to make the stop. When the handle is placed in any of the graduated notches of the service position, train-pipe pressure reduces through ports *F* and *G*, in valve *114*, Fig. 24, and passage *C*, in the brake-valve body, as shown in Fig. 29. This figure shows the positions of the different valves, etc. when the brake-valve handle is in the second graduating notch. It is not then necessary to pull the handle of the valve back to lap position in order to close the train-pipe exhaust, as the port *F*, Fig. 20, in valve *114* will be automatically lapped by cut-off valve *110*. The automatic lapping of port *F* in

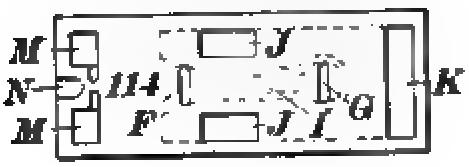


FIG. 24.

a

D

FIG. 19.

FIG. 20.

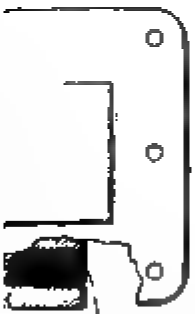


Fig. 23.

M
er

To Train

Fig. 22.

Fig. 21.

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valve *114* in service applications is accomplished in this way: The air in chamber *A*, in front of piston *104*, has the same pressure as that in the train pipe, and its pressure commences to reduce the moment port *F* in valve *114* is moved off cut-off valve *110*, and uncovered. The pressure of the air in the supplementary reservoir *155* is equal to that in chamber *A* and in the train pipe before the reduction begins. When valve *114* is moved to service position, port *H* leading train-pipe air to supplementary reservoir *155* is lapped, and the air confined in *155* and in chamber *D* behind piston *104* now acts as an independent force on the piston and automatically moves the piston until the cut-off valve closes port *F*, thus lapping the valve. As the train-pipe pressure in chamber *A* reduces, piston *104* is moved forwards from its release position by the greater pressure behind in chamber *D* and the supplementary reservoir *155*, which, by means of lever *112*, moves cut-off valve *110* until port *F* in the face of valve *114* is blanked, thus stopping the escape of air from chamber *A* and the train pipe. This is shown in Fig. 30.

64. The fifth position of the brake-valve handle is the *emergency position.* Whenever there is danger of accident or loss of life or property, the handle of the valve is instantly placed in emergency position. When in the emergency position, the air in the train pipe escapes quickly through the large ports *J*, *J*, and *K*, Fig. 24, in valve *114*, and exhaust passage *C*, in the valve body, to the atmosphere. This large opening allows train-pipe pressure to reduce so quickly that the quick-acting parts of all the quick-action triple valves are thrown into operation, and all brakes throughout the whole train are applied with full force. Fig. 31 shows the valve in emergency position.

In looking over the different figures of the brake valve, it will be observed that the pump governor is connected to the brake valve at *a*, Figs. 17, 21, and 22. This connection leads directly into chamber *E*, Figs. 17, 19, 20, 23, and 28, so that the pump governor is operated by chamber *E* pressure. Chamber *E* is on the train-pipe side of the excess-pressure valve, and is always in direct communication with chamber *B* and main-reservoir

pressure through that valve; hence, the pressure in chamber *E* is maintained 20 pounds less than main-reservoir pressure with the brake valve in either lap or service positions. In those positions, the slide valve *114* closes communication between chamber *E* and chambers *B* and *A*, and the pressure in chamber *E* is maintained at 70 pounds. This prevents the pump working during the time the brakes are applied, and so prevents excessive main-reservoir pressure being pumped.

It will be seen, also, that the gauge connection for the black hand of the air gauge, which indicates train-pipe pressure, and the connection for the red hand, which indicates main-reservoir pressure, are shown in Figs. 16 and 17. The pin *113*, Fig. 18, is the fulcrum pin for the lever *112*, Fig. 22.

OPERATION.

65. Applying Brakes.—Having charged the train pipe, and the auxiliary, supplementary, and main reservoirs to standard pressure, that is, to 70 pounds and 90 pounds, the brake is applied in the service application by moving the handle *123*, Fig. 17, to the first graduating notch of the service position. This moves the main slide valve *114*, Fig. 20, back a sufficient distance to bring port *G* over exhaust port *C*, and, at the same time, port *F* will be moved back so that cut-off valve *110* does not cover it, as shown in Fig. 29. Air from the train pipe can now enter the cavity of the main slide valve through port *F*, and escape through port *G* and exhaust port *C* to the atmosphere.

As the air from the train pipe escapes to the atmosphere, the pressure in the train pipe reduces. The pressure of the air in the supplementary reservoir *155* and chamber *D*, which was equal to train-pipe pressure before reduction began, is now greater, and commences to push piston *104* forwards. As piston *104*, which is connected to cut-off valve *110* by means of the lever *112*, moves forwards, cut-off valve *110* is moved backwards (or in the same direction that main valve *114* was moved when the handle *123* was placed in the first graduating notch), until it comes under and blanks port *F*, Fig. 30. When this

FIG. 29.

Fig. 27.

Fig. 29.

Fig. 30.

Fig. 31

occurs, no more air can escape through port *F* from the train pipe, and the valve is said to be automatically lapped. The amount of reduction made in the train-pipe pressure, with the handle in the first graduating notch, is about 4 pounds, or an amount usually sufficient, when the train is short, to force the pistons in the brake cylinders over the leakage grooves.

66. To apply the brakes a little harder, another reduction is necessary, so the handle *123* must be placed in the next graduating notch of the service position. Main valve *114* will be moved farther to the right, away from cut-off valve *110*, and port *F* will again open for the escape of train-pipe air as before. Port *G* will still connect with exhaust port *C* in the seat, on account of the wide opening of the port, and communication between train pipe and atmosphere is again established. As train-pipe pressure reduces, piston *104* moves forwards again by reason of the greater pressure in supplementary reservoir *155* and in chamber *D*, until cut-off valve *110* again blanks port *F* and prevents the air in the train pipe from exhausting.

This second reduction in train-pipe pressure causes the brakes to set a little harder, and as the handle *123* is moved along into the remainder of the graduating notches, the brakes apply harder and harder, until the last graduating notch is reached, when the brakes are applied in full force.

67. The stroke of piston *104* and the travel of cut-off valve *110* are such that when handle *123* is placed in the last graduating notch, a reduction of 25 pounds in train-pipe pressure will be had before cut-off valve *110* can lap port *F* in main slide valve *114*.

68. Releasing Brakes.—To release the brakes, place handle *123* in the position marked "*Full Release,*" Fig. 26. When handle *123* is in this position, main valve *114* is moved to its extreme forward position, port *A* in its seat, Fig. 23, is uncovered, and a large, direct communication is established between the main reservoir and train pipe (see Fig. 26). Port *A* is made large so that main-reservoir pressure can get back through the train pipe with considerable energy

and force all the triple valves to release. At the same time that handle *123* is in full-release position, and air at main-reservoir pressure is recharging the train pipe and auxiliary reservoirs, the air confined in supplementary reservoir *155* and chamber *D*, behind piston *104*, is exhausting to the atmosphere through ports *H*, *J*, and the exhaust passage *C*; ports *J*, in slide valve *114*, then connecting port *H* with port *C*, Figs. 21 and 23. As the air in chamber *D*, behind piston *104*, escapes, train-pipe pressure in chamber *A* forces piston *104* and, consequently, cut-off valve *110*, back to their normal position, as shown in Fig. 26. This allows the air in the main reservoir to feed into the train pipe, as shown in Fig. 26, thus causing the triple valves to act and release the brakes.

69. In bringing handle *123* back to the running position, supplementary reservoir *155* and chamber *D* are charged from the train pipe, the air flowing through port *J* in valve *114* and port *H* in the valve seat.

It will be well to remember that the air in supplementary reservoir *155* is for the sole purpose of moving piston *104* and cut-off valve *110* in service application, and that it is only when the handle *123* is in running and lap positions that the supplementary reservoir can be charged up from the train pipe.

70. Emergency Application.—In an emergency application, the handle *123* is thrown clear over to the position marked "*Emergency*," Fig. 17. Main valve *114* is thus moved to its extreme backward position, and port *K* is brought squarely over exhaust port *C*. The large port *K* is connected with ports *J*, *J* by a passage running lengthwise through main valve *114*, and indicated by the outer dotted lines on face of Fig. 24. Ports *J* and *J* are open to air from the train pipe, and through these ports, port *K*, and exhaust port *C*, air in the train pipe can quickly escape to the atmosphere (see Fig. 31). This reduces the train-pipe pressure very rapidly and causes the triple valves to act very suddenly.

71. In releasing the brake after an emergency or service application, it is important that the brake-valve handle be left

in full-release position long enough to relieve the supplementary reservoir of its pressure before the valve is moved to lap or running position, otherwise the valve will not automatically lap or graduate in the next service application.

The positive lap position is necessary in order that communication can be cut off between the main reservoir and the train pipe in the event of a hose bursting, or the train breaking in two, thus preventing the loss of main-reservoir pressure; also, this position is used to prevent the releasing of the brakes when applied from a conductor's valve.

Also, if a second application is to be made immediately after releasing, the brake-valve handle must first be left in either running or lap position for a couple of seconds so that the supplementary reservoir will become charged, otherwise the automatic cut-off of the brake valve will not work as usual and a full-service application will result if the valve is not lapped by hand.

THE NEW YORK AIR BRAKE.

(PART 2.)

DEFECTS AND REMEDIES.

THE PUMP GOVERNOR.

ITS IMPORTANCE.

1. The **air pump** is the life of the air-brake system, since its duty is to supply air, without which the brakes cannot be operated. Anything that renders the pump inoperative, therefore, makes the air-brake system useless.

The **pump governor** is a throttle valve whose duty is to automatically control the air pump; hence, any disorder in the governor will affect the working of the pump and make the brake system less reliable and effective, or, until cut out, it may render the system entirely useless.

IMPROVED GOVERNOR.

2. Failure to Operate the Pump Properly.—If the governor does not operate the pump properly, and cannot be made do so by adjusting the tension of the spring *10*, the trouble may be due to any of the following causes: (1) Leaky diaphragm valve; (2) steam valve held open by solid matter on its seat; (3) relief port *e* stopped up; (4) drip pipe frozen or stopped up; (5) governor piston stuck in bushing.

1. *Leaky Diaphragm Valve.*—This may be due to the diaphragm valve, Fig. 3,* not seating properly; or to solid matter,

* All figure numbers used in this Section refer to the illustrations in *The New York Air Brake*, Part 1.

such as dirt, gum, or scale, holding the valve from its seat. A leaky diaphragm valve allows air at train-pipe pressure to pass from chamber *a* past diaphragm valve and through passage *b* into chamber *c* above the governor piston *4*. If the air leaks past the valve faster than it can escape through the relief port *e*, pressure will accumulate in chamber *c* and force the governor piston downwards, so as to either wholly or partially close the steam valve *25*. If the steam valve is closed, the pump will of course stop; if only partially closed, the steam supply will be throttled and the pump will work more slowly than usual. A slight leak past the diaphragm valve will simply make the governor less prompt in starting the pump after the diaphragm valve closes, and it will be indicated by a constant discharge of air from the relief port *e*.

The diaphragm valve may be removed for cleaning by unscrewing the spring box from the diaphragm body.

2. *Steam Valve Held Open.*—If the steam valve *25* is held from its seat by dirt or solid matter, the pump will continue to work and increase the pressure in the main reservoir until the pressure is sufficient to stop it. In this case, the diaphragm valve works properly, and opens when a train-pipe pressure of 70 pounds is obtained, but the dirt on the seat of the steam valve prevents the steam valve from closing, and the pump, consequently, continues to work, although at a slower speed than usual. A *leaky steam valve*, also, will cause the pump to make a stroke occasionally.

3. *Relief Port Stopped Up.*—It will be remembered that the duty of the relief port *e* is to allow the air to escape from chamber *c* when the diaphragm valve closes, so that the pump will start promptly. If port *e* is stopped up, this means of escape is cut off, and the air will have to leak past the packing ring *24* and out of the drip pipe. The rapidity with which it will do this depends on the fit of the packing ring; if this fit is at all snug, the governor steam valve *25* may not open for some time after the diaphragm valve closes. In this case, therefore, it is possible for leaks to reduce main-reservoir pressure several pounds before the pump begins to work.

4. *Drip Pipe Stopped Up.*—If the drip pipe is frozen or stopped up and the stem of the steam valve *25* is worn, steam will feed up into the chamber *d* under the governor piston and prevent the piston from being forced downwards to close the steam valve *25*. The pump, therefore, will continue to work until sufficient pressure is accumulated to stop it. A worn steam-valve stem will be indicated by steam escaping from the drip pipe—if the latter is not stopped up. Even though the stem does not leak sufficiently to prevent the steam valve from being closed, the pump will continue to work, for air will leak down past the piston packing-ring as soon as the diaphragm valve opens, and accumulate under the piston. This soon raises the piston, and thus opens the steam valve. The pump then starts and continues to work until stopped by the pressure in the main reservoir.

5. *Governor Piston Stuck in Cylinder.*—If the governor-piston cylinder becomes badly worn, the piston is liable to stick at the lower end of its stroke, especially if a new ring is fitted without truing up the cylinder, and the pump will not start. A light tap on the governor or on the steam pipe near it is usually sufficient, however, to start it operating again.

CUTTING OUT A GOVERNOR.

3. In case a **governor becomes disabled,** it may be cut out by placing a blind gasket in the air pipe leading to it, as, for instance, in the union at *Z*, or by plugging the small opening *b* that leads into chamber *c*. In either case, pressure will be excluded from chamber *c*, and, consequently, the steam valve will remain open, thus providing a free passage for the steam through the governor.

THE AIR PUMP.

PACKING THE PUMP.

4. The life and efficiency of an **air-brake pump** depend to a great extent on the care it receives. In packing such a pump, any substance that will harden, such as asbestos, should not be used. Also, care should be exercised not to screw the

packing-gland nuts too tight, as the rubbing friction between the piston rod and packing, when the latter is pressed too hard against the former, may produce sufficient heat to burn the packing out, and cause unnecessary trouble on the road. If the gland nuts can be screwed up sufficiently by hand to prevent a blow, no wrench should be used. A blow should be stopped as soon after it occurs as possible, as the steam tends to cut a channel along the piston rod through the packing, and thus spoil it.

A swab saturated with oil should always be used on the piston rods. This not only serves to keep the rod and packing, but also the air cylinders, in good condition, as some of the oil works upwards into the air cylinders and helps to lubricate them.

OILING THE PUMP.

5. Quantity of Oil Necessary in Steam Cylinders. A sufficient quantity of good oil should be used in the steam cylinders to keep the parts well lubricated and prevent groaning. The quantity of oil necessary will depend on the kind of oil used, and also on the pump itself, as some pumps require more than others. If the pump groans constantly, and the pump exhaust or the drip pipe shows that considerable water is working through the steam cylinders, its dry pipe should be examined for leaks that will allow water to reach the pump and wash out the oil.

6. Quantity of Oil Necessary in Air Cylinders. The quantity of oil to be used in the air cylinders depends to a great extent on the pump, but in any case it should be used very sparingly. The amount should only be sufficient to keep the packing rings free, and prevent cutting of the walls of the cylinder. If too much is used, a gummy deposit is formed in the air cylinder and air passages and on the air valves, which tends to cause heating; also, oil works back into the brake valve and triples, and causes them to work poorly. A small quantity of good valve oil is best to use in air cylinders. The oil may be fed to the cylinder by means of a swab on the piston rod, or through the air-cylinder oil cups, *but it should*

never be fed through the air inlets, as it will close the air passages, gum up the valves, reduce their lift, and sooner or later result in overheating. Animal or vegetable oils should not be used in the air cylinders, as they gum very readily; also, mineral oils that have a low flashing point, as, for instance, kerosene, should not be used in a hot cylinder, as they generate an explosive gas that ignites at a comparatively low temperature, and trouble, therefore, may result from their use. When the air end of the pump begins to groan, a small quantity of good valve oil should be introduced through the oil cup to the high-pressure air cylinder, as this is the cylinder in which the compression is the highest. The larger, or low-pressure, air cylinder will seldom require any oil through its oil cup if the swab on the piston rod is kept well oiled and in good condition.

CLEANING OUT THE PUMP.

7. Occasionally, the air cylinders of an air pump get a fit of "groaning." When this occurs, the upper air-cylinder head should be removed, the pistons pushed down to the lower end of the cylinders, and the cylinders thoroughly cleaned by means of a piece of waste saturated with kerosene. The cylinders should then be wiped out thoroughly with clean waste, and oiled lightly with a good grade of mineral oil or vaseline, after which the head may be replaced.

RUNNING THE PUMP.

8. Starting.—When first starting an air pump, the drip cock *54*, Fig. 4, should be opened, and left so until the pump is thoroughly warm, and it should be started slowly to allow the water of condensation to escape gradually, and to prevent pounding. No provision is made in the steam end of an air pump for bringing the piston to rest easily by means of cushioning, since, when the pump is working against pressure, the air in the air cylinder acts as a cushion. When the pump is first started, however, there is little or no pressure in the main reservoir, and, consequently, there is nothing to prevent the pistons striking the cylinder heads violently if the pump throttle is opened very wide. For this reason, the pump

should be run slowly until sufficient pressure is accumulated to cushion the pistons.

After the pump is warm, the drip cock should be closed, and the throttle may be opened wide enough to run the pump at the required speed. The air-pump lubricator should be started as soon as the pump is, since, by oiling the cylinder well at the start, less oil will be necessary afterwards to keep it working smoothly. If the pump groans badly in the steam cylinder, it may be due to loose governor connections, or the drip cock leaking or working open, and allowing the oil to escape instead of going into the pump. See that all steam connections to the pump are tight, and drip cock closed; then, if it groans, allow a few extra drops of oil to feed into it from the lubricator.

9. Pump Speeds.—To obtain the best results from a pump, it should not be run at a slower speed than from 45 to 60 strokes a minute. The speed may be increased as occasion demands, but "racing" should be avoided, as it causes overheating.

If a pump is run too slowly, some of the air, being compressed, will leak by the packing rings, and expand and fill the other end of the cylinder, and thus less fresh air will be drawn in through the suction valves at each stroke; in consequence of this, the pump heats and its efficiency is greatly reduced. When the pump is run at its proper speed, however, the air has less time in which to leak by the piston packing-rings; consequently, the pump heats less and its efficiency is greater.

THE AIR VALVES.

10. Lift.—The lift of all air valves in the No. 1 and No. 2 pumps should be $\frac{1}{16}$ inch.

PUMP TEMPERATURE.

11. Working Temperature.—The normal temperature of a pump depends on (1) the quantity of air it compresses; (2) the rate at which the air is compressed; (3) the pressure against which the pump works; (4) the temperature of the air before compression.

1. *Quantity of Air Compressed.*—The greater this quantity, the more continuously, or the faster, the pump will have to work in order to compress it; hence, the greater the normal temperature of the pump.

2. *Rate of Compression.*—Experiment shows that the faster the air is compressed the higher its final temperature will be; also, the faster the pump is run the less time there is for the radiation of heat between strokes; hence, since more heat is generated, and less radiated at each stroke of the pump, it is evident that the temperature of the pump must increase with its speed.

3. *Resisting Pressure.*—More power is employed when working against a higher than when working against a lower pressure; therefore, heat is generated at a greater rate. Also, experiment shows that the final temperature of air under compression increases with the pressure.

4. *Temperature of Air Before Compression.*—Experiment shows that air at 0° F. will have a final temperature of about 360° F. when compressed to 90 pounds pressure, while air at 100° F. will have a temperature of about 530° F., the speed of the compressor being the same in both cases.

EXCESSIVE HEATING OF PUMP.

12. Causes.—The overheating of a pump may be due to one of the following causes: (1) Continuous high speed; (2) excessive pressure to work against; (3) air-piston rings badly worn; (4) air cylinder leaking; (5) main-reservoir air leaking back into air cylinder; (6) air passages in pump, or air-discharge pipe partially stopped up; (7) air valves stuck shut.

1, 2. *Continuous High Speed, or Excessive Pressure.*—How either of these causes will result in excessive heating has already been explained (see preceding article).

3. *Leaky Piston Packing-Rings.*—This defect will cause a pump to overheat more quickly, and to a higher degree, than any of the other causes; consequently, the air-piston packing rings should receive frequent attention.

When the packing rings are badly worn, air can leak by

them in either direction; consequently, less air is taken into the cylinder, and less forced into the main reservoir at each stroke, than if the rings were tight. As the piston moves forwards it compresses, and therefore raises the temperature of the air in front of it; some of this air then escapes past the piston, and raises the temperature of the incoming air considerably, *before it is compressed.* This results in a still higher final temperature of the air when compressed, and that portion which in its turn escapes past the piston is at a higher temperature, and hence heats the incoming air to a higher degree than in the previous stroke. At each stroke of the piston, the air that leaks by is hotter than in the previous stroke, and raises the temperature of the incoming air still more, until finally the pump is badly overheated. There is also another effect due to leaky packing rings: Since the pump neither takes in nor discharges as much air as it would if in normal condition, it follows that a greater number of strokes will have to be made to pump up main-reservoir pressure; consequently, the pump will have to work faster or for a longer time than usual, either of which contingencies will help to overheat it.

To test for worn packing rings or cylinder, run the pump at a moderate rate of speed and against full main-reservoir pressure. If on either of the up or down strokes, air is drawn in feebly for first part of stroke and then the suction ceases as the piston nears the end of its stroke, it indicates leakage past the packing rings. To determine in which cylinder of the duplex pump the leaky rings are located, hold the hand close to the lower inlet valves and watch the upward stroke of the piston in the large cylinder. If the suction ceases before the piston completes its stroke, it is proof that the rings in the low-pressure cylinder are leaking. Leaky rings in the high-pressure air cylinder are found in the same way; as, if they leak, the suction at the air-inlet valves will cease before that piston completes its stroke.

Another test is to open the air-cylinder oil cups, and if air blows out of the cups as their respective pistons are nearing the end of the downward stroke, the upper, final, and intermediate discharge valves being tight, it is an indication of the worn condition of the packing rings.

4. *Leakage From the Air Cylinder.*—Any such leakage, either through a leaky or broken receiving valve, or a blow in the piston-rod packing, reduces the amount of air pumped per stroke, and the pump must either be run faster or for a longer time to compress a given amount.

A *leaky receiving valve* is indicated by air blowing back past the valve as the piston moves toward it. Also, it causes the piston to take a quicker stroke when traveling in that direction.

A leaky receiving valve for the low-pressure air cylinder is indicated by air blowing out as the piston approaches it, and a quicker stroke of the piston when moving in the direction of the leaky valve.

To test for a leaky receiving valve for low-pressure cylinder, hold the hand near the air-inlet ports; air will be sucked in as the piston moves from the leaky valve, and forced out as it moves toward it.

To test for a leaky upper discharge valve 11 for the low-pressure cylinder, run the pump slowly, and, as the high-pressure piston starts upwards, open the low-pressure cylinder oil cup; a blow from this cup during the up stroke indicates that the valve leaks.

To test the lower discharge valve 12 for the low-pressure cylinder, unseat the lower receiving valve *10* with a wire nail; if air blows from the air inlets as the high-pressure piston moves down, the valve *12* leaks.

5. *Back Leakage From Main Reservoir Into High-Pressure Cylinder.*—This defect may be due to a broken or leaky final-discharge valve or valve seat. The test to determine whether there is such a leak should be made as follows: When main-reservoir pressure is about 90 pounds, shut steam off in time so that both pistons will stop at the bottom of these cylinders, and open the high-pressure cylinder oil cup; if a steady blow occurs from the cup and the piston remains stationary, the upper final-discharge valve is leaking; whereas, if no blow occurs and the piston moves up, the lower final-discharge valve is leaking.

6. *Air Passages or Discharge Pipe Stopped Up.*—Occasionally, the air passages or the air-discharge pipe becomes partly closed with gum and dirt. This increases the back pressure on the pump. It has another effect also: when the air-inlet passages

are choked, the pump does not draw in as much air at a stroke as it should; while a choked discharge pipe increases the leakage past the piston rings, and more power is necessary to force the air into the main reservoir. These effects will cause the pump to run slower than usual, and heat.

If the air valves have too little lift, the effect will be the same as though the air passages were choked. If only one of the valves has too little lift, the strokes of the pump will be uneven—the faster stroke being toward the defective valve, if a receiving valve, or from it, if a discharge valve.

7. *Air Valves Stuck Shut.*—If it is a receiving valve, there will be no suction as the piston moves away from it; the strokes of the pump will be uneven, the one toward the defective valve being the faster. The pump will probably pound on the fast stroke, and it will also become heated. The reason why the strokes are uneven is that the vacuum formed in the end of the cylinder in which the stuck valve is, works *against* the steam pressure on the stroke away from the stuck valve, and *with it* on the return stroke. If both receiving valves are stuck, there will be no suction on either stroke of the pump; the pump will pound and heat, and the red hand of the gauge will not move forwards. The strokes, however, will be even, but the pump will run faster than usual. If the air-inlet ports become frozen or stopped up, the effect will be the same as though both receiving valves were stuck shut.

If a discharge valve is stuck shut, the strokes of the pump will be uneven, the *slow stroke* being *toward* the defective valve; there will be no suction as the piston moves *away* from it, and the pump will heat. The reason why the strokes are uneven is as follows: The cylinder is full of air as the piston starts toward the stuck valve, and since the valve is closed and the air cannot escape, it is compressed and offers a steadily increasing resistance to the movement of the piston. The stroke away from the stuck valve is assisted by this compressed air, which acts like a compressed spring to force the piston along. As the force exerted by the air acts against the steam pressure in the first instance, and with it in the second, it is evident that one stroke will be faster than the other.

Should both discharge valves stick, the pump will run faster than usual and heat badly, and there will be no suction on either stroke, the piston simply churning back and forth in the cylinder. In this case, also, the red hand of the gauge will not move forwards. If the discharge pipe is frozen or stopped up, it will have the same effect as if both discharge valves were stuck shut.

When the strokes of one of the pistons are uneven, the pump is generally referred to as being "lame."

Stuck valves are generally due to the valve and valve seat wearing so as to form a very broad bearing surface, although gum may help to stick the valve; also, back leakage from the main reservoir or past the piston packing may tend to hold the valve to its seat. Gum causes the valves to wear rapidly and often causes them to break.

It has been found that the upper intermediate discharge valve generally wears more rapidly than the other valves.

A *small main reservoir* used in heavy freight service is often the cause of the air pump overheating, since it does not hold sufficient air to release the brakes and recharge the auxiliaries promptly, and the pump, in consequence, must be worked faster when the brakes are released. A pump is not as efficient when hot as when cold, since air, on entering a hot cylinder, expands, and consequently less is required to fill it at atmospheric pressure; hence, the pump when hot, must make a greater number of strokes, to do a given amount of work, than when cold.

POUNDING IN PUMP.

13. Causes.—Pounding in an air pump may be due to any one of a number of causes. It may be due to water in the cylinder; to the pump being loose on the brackets that hold it, the brackets being loose on the boiler, or to pipes being loose; to the pistons striking against cylinder heads; to the nuts *74*, Fig. 4, working loose and striking the air-cylinder head; or to the air valves pounding on their seats, due to too much lift. A piston being slightly loose on its piston rod will cause a click, and it is found that the air pistons give more trouble in this respect than the steam pistons.

The *clearance in an air pump* is purposely made as small as possible, the air as it is compressed in the air cylinder being relied on to act as a cushion for the pistons, to prevent their striking the cylinder heads. Packing rings that are badly worn, or receiving valves that are stuck, broken, or leaky, will reduce this cushioning effect of the air and hence allow the pump to pound. Also, a loose reversing plate may cause a click.

DUPLEX PUMP STOPS.

14. In the steam head of the duplex pump there is a drain cock *54*, which, if opened, will indicate (if steam blows through it strongly) that the governor is not at fault. If no steam blows through, or only blows feebly, the cause of the trouble lies in the governor. Other causes for the pump stopping are: (1) badly worn or loose reversing plates; (2) broken reversing rods; or (3) loose nuts on the ends of air piston.

1. *Worn or Loose Reversing Plates, or Worn Rods.*—If the reversing plates become badly worn or very loose, or the button on the rod becomes worn, they may prevent the pump from being reversed.

2. *Broken Reversing Rods.*—If a reversing rod breaks, or if the button *u* on its head pulls off, the pump will stop.

3. *Loose Air-Piston Nuts.*—If none of the causes already mentioned have stopped the pump, remove the top air-cylinder head and examine for loose nuts on piston rods, or for pieces of broken air valves between piston and cylinder head, which prevents the pump completing its stroke and operating the reversing valve.

DUPLEX PUMP BLOWING.

15. A blow will occur in the steam end of the pump (1) if the ends of the reversing rods in the cap nuts are worn; (2) if the reversing slide valves are cut or their seats defective, so that steam can escape into the exhaust passage; (3) if the packing rings in the steam piston are worn or broken or the cylinder worn or cut.

1. *Worn Reversing Rods.*—If the ends of the reversing rods become worn so that steam can escape by them into the cap nuts, it will return through the passage drilled in the rods to the lower end of the steam cylinder, and will cause a slight blow on the downward stroke of the piston in which it is working, since that end of the cylinder will then be open to the exhaust.

2. *Reversing Valves Leaking.*—If one or both of the reversing valves are leaking, or if their seats are defective, steam can escape from the slide-valve chamber direct into the exhaust ports, and a constant blow will be produced.

3. *Worn or Broken Steam Packing Rings.*—If the packing rings on the steam pistons are worn or broken, steam will pass by them from one side to the other and escape through the exhaust opening.

It is difficult to distinguish between a blow from a leaky slide valve, a worn cylinder, or worn packing rings, without taking the lower steam cylinder head off for inspection.

QUICK-ACTION TRIPLE VALVE.

TIME REQUIRED TO CHARGE AUXILIARIES.

16. Effect of the Size of Feed Groove.—The triple valve, like any other mechanism that is used under varying conditions, and is subject to rough treatment, is liable to certain disorders, and it is of these that we will now treat. As soon as an engine is coupled to a train, the engineer should charge the air-brake system. Air from the main reservoir is forced back through the train pipe, thence through the feed grooves of the triples, and into the auxiliary reservoirs. The feed groove is made of such size that, with a constant train-pipe pressure of 70 pounds, it will charge an auxiliary from zero to 70 pounds in about 70 seconds. A train with fifty auxiliaries would charge as quickly as a single auxiliary, if the pump could keep the train-pipe pressure constant at 70 pounds; but as it cannot do this, more than 70 seconds is required to charge the train. On a train of only four or five cars, the auxiliaries will

charge in about the same length of time as a single auxiliary; but, with longer trains, the time of charging depends on the size and condition of the pump, the speed at which it is run, the number of auxiliaries to be charged, and the extent of leaks in the train pipe and auxiliaries, etc.

17. Auxiliary Charges Too Slowly.—The feed groove is of such size that, with everything in good condition, it will charge an auxiliary at the average rate of about 1 pound per second from a train-pipe pressure of 70 pounds. The time of charging, however, does not depend entirely on the feed groove, and it will be increased by any of the following causes: (1) The small openings in the strainer *28* in the triple valve, Fig. 8, may be partially stopped up, so as to restrict the flow of air to the triple valve; (2) the feed groove may be partially closed with gum or dirt; or (3) the auxiliary reservoir may leak.

If oil, cinders, scale, pipe fins, etc. get into the train pipe, they may clog the strainers and feed grooves or cause wear that will allow auxiliary pressure to escape to the atmosphere. Dirt and cinders will work into the train pipe if the brake hose is not hung up properly when not in use; oil will work back from the pump, if used too freely in the air cylinder; scale may come from the inside of the pipes, if they are not properly treated before being applied to a car, and also from the pipes corroding; and pipe fins, if not removed by the pipemen, may work loose and cause trouble.

18. Effect of Working Conditions.—It will thus be seen that the condition of strainers and triples may not be the same on any two cars of a train; hence, the time required to charge the different auxiliaries may vary considerably, and sufficient time should be allowed, when possible, for all the auxiliaries to become fully charged before the brake valve is placed on *lap*, or the brakes applied again. If the valve is *lapped* while some of the auxiliaries are undercharged, they will continue to take air from the train pipe until they equalize with it, and thus may reduce train-pipe pressure sufficiently to apply the brakes on the cars on which the auxiliaries were fully

charged. On the other hand, if a service reduction is made while some of the auxiliaries are undercharged, the latter may not apply the brake on their cars at the first reduction, and they will continue to take air from the train pipe until they equalize with it; in this case, the other brakes will set harder than is intended.

EFFECT OF TRAIN-PIPE AND AUXILIARY LEAKS.

19. Train-Pipe Leaks.—Leaks in the train pipe not only increase the time required to charge the auxiliaries, but, after the brakes are applied, they cause the triples to gradually apply the brakes harder. A leak at any part of the train pipe affects all the triples, since the train pipe is continuous throughout the train.

20. Auxiliary-Reservoir Leaks.—As long as the brakes are off and the triples are in *release* position, Fig. 8, the pump will probably be able to make good any leakage of auxiliary pressure, and no harm will be done, aside from keeping the pump at work to supply the leak. When the brakes are applied, however, and the triple valves are in service position, Fig. 9, a reduction of pressure in any auxiliary will allow train-pipe pressure to force its triple piston to release position, and release the brake on that car. Then, since the feed groove is open in this position, air from the train pipe will feed into the auxiliary to supply the leakage and to charge the auxiliary to train-pipe pressure; hence, a reduction will be made in train-pipe pressure that will tend to apply the other brakes harder. It is possible, however, for the auxiliary reservoir to leak, and still not cause the brake to "leak off" or release. If train-pipe leaks reduce train-pipe pressure at the same rate that the auxiliary leak reduces auxiliary pressure, the brake will not leak off; or, if the packing ring *3*, Fig. 8, is much worn, sufficient air may leak past into the auxiliary reservoir to supply the leak and thus prevent the brake releasing.

Leakage of auxiliary air at the triple exhaust is generally due to dirt on the seat of the exhaust valve; a worn exhaust-valve seat; a leak in the gasket that is between the triple valve

and the brake cylinder (see passenger equipment, Fig. 7); or to the gasket *15* that is between the triple valve and the auxiliary reservoir in the freight equipment, Fig. 11.

IMPORTANCE OF GRADUATING VALVE.

21. The **graduating valve** *48*, Fig. 8, is the part of the triple that makes it most sensitive. If there were no graduating valve, but simply the service or graduating port *l*, and if the exhaust valve were fastened firmly to the stem of the piston, the brakes could still be applied and released; but the triple valve would not be nearly so sensitive, and greater reductions would be necessary to move the parts. For instance, when a reduction of train-pipe pressure was made, the triple would assume service position, but it would not assume lap position until a sufficient difference of pressure existed between the auxiliary and the train pipe to allow the latter pressure to not only overcome the friction of the triple piston packing ring, but also the friction of the exhaust valve, before the graduating valve would be forced back far enough to close the service port *l* (lap position). Then, when it was desired to apply the brake harder, a much greater train-pipe reduction than usual would be necessary to move the triple piston to service position again, since auxiliary pressure, acting on the triple piston, would also have to overcome the friction of the exhaust valve.

TRIPLE-VALVE LEAKS AND DEFECTS.

22. The most common cause of trouble in the quick-action triple valve, are (1) triple strainer or the feed groove stopped up; (2) leaky graduating valve; (3) triple gummed up. Other defects are, (4) brake releasing when applied; (5) brake failing to release; (6) brake applying quick action; and (7) brake failing to apply quick-action.

1. *Strainers or Feed Groove Stopped Up.*—Sometimes a triple valve will not set the brake properly on a car in response to a train-pipe reduction. This may be due to the triple strainer being partly stopped up or the feed groove so stopped up as to

prevent the auxiliary charging fully, or the triple may be so gummed up and dirty that the triple piston cannot move. In the latter case, the brake on this car will not apply with a service application either. However, if a sufficiently heavy reduction is made, the triple piston may be torn loose, in which event it may not give much trouble during the remainder of the trip.

When a quick-action triple in a train applies a brake in emergency, the quick-action part of the triple takes air from the train pipe suddenly and vents it out to the atmosphere. This sudden reduction is sufficient to start the next quick-action triple into emergency, the next one following, and so on throughout the entire train. If two or three cars with dirty strainers or with brakes cut out are placed together near the head end, the sudden reduction made by the quick-action triple ahead of these may not be sufficient to work the next quick-action triple immediately behind them, owing to the effect of friction on the flow of air through the train pipe of the cars cut out destroying the suddenness of the reduction by the time it has reached the rear end of the last car that is cut out; hence, the quick-action effect cannot be obtained on these cars or the ones back of them. On the other hand, if the engineer makes an emergency application and "laps" the brake valve too quickly, the air from the rear cars will flow ahead and "kick off" the head-end brakes, and only a light service application will be obtained on the brakes back of the ones causing the trouble. If the brake-valve handle is left in emergency position, however, full emergency action will be had on the cars ahead, and full service on those back of the ones causing the trouble.

2. *Leaky Graduating Valve.*—In lap position of the triple, a leaky graduating valve will allow auxiliary pressure to escape under the graduating valve and through port *l* into the brake cylinder, thus applying the brake harder and reducing auxiliary pressure. Whether or not this reduction of auxiliary-reservoir pressure will allow the brake to release will depend on the condition of the triple piston packing ring. If it is tight then auxiliary pressure will continue to leak into the brake

cylinder until a sufficient difference of pressure exists between the train pipe and the auxiliary to start the exhaust valve moving, when it may move to release position and release the brake.

If air can leak by the piston packing-ring into the auxiliary reservoir as fast as it leaks by the graduating valve into the brake cylinder, the brake will continue te set harder instead of releasing. With a full application of the brakes, the auxiliary and brake-cylinder pressures are equal; therefore, under such conditions a leaky graduating valve cannot release the brake.

3. *"Sticky" Triples.*—A sticky triple is sometimes the cause of the brake applying *quick action* on a car during a gradual train-pipe reduction. Generally, when a triple sticks, it does not respond to the first, and, in some cases, to the second, service reduction, and the brake on that car does not set; usually, with the next reduction, the difference in pressure between the auxiliary and the train pipe is such that the triple piston is torn loose from the gum and caused to move quickly forwards to emergency position, the stem *129* striking with sufficient force to compress spring *132* and open the emergency valve *71*; thus causing an emergency application of the brake on that car, while the application of the other brakes is increased slightly, also.

Test to Locate a Sticky Triple.—To locate a sticky triple, make a service reduction of 5 or 6 pounds, and then look for the brake piston that has not moved out. Cut this brake out, and repeat the test to be sure that the faulty triple has been properly located.

Whenever a quick-acting triple becomes very dirty and sticky, and is giving trouble on this account, it can be detected by the flash of air at the vent port *M*, Fig. 9; hence, another good method of locating a sticky triple is to cut in a small portion of the train at a time, and then try to locate the faulty triple by the quick movement of the brake piston and the flash of air at the vent port *M*, which indicates that the triple has gone into quick action.

4. *Brake Releases When Applied.*—Should a brake release after having been set, it may be due (*a*) to the auxiliary pressure leaking past the emergency valve *138* or its cap nut, a leak

past the emergency valve being indicated by a blow at the vent ports *J*; (*b*) check-valve *117* may be leaking and thus allowing the brake-cylinder pressure to escape through the passage *L*, past the stem of the emergency piston *137*, and out to the atmosphere through the ports *J*, this leak also causing a blow, as does a leaky emergency valve. However, a leaky emergency valve will cause a constant blow, whereas a leaky check-valve *117* will only cause a blow during the time there is pressure in the brake cylinder.

5. *Brake Fails to Release.*—If a brake fails to release and there is a strong blow at the vent ports *J* and *M*, the trouble is probably due to the vent valve *71* being held from its seat; this may be caused by the stem of the vent-valve piston being bent, or else the piston itself may be caught in its cylinder, or perhaps dirt or scale has collected between the valve and its seat; also, the brake will fail to release if the triple piston packing ring is badly worn and train-pipe pressure is raised slowly, especially if the train is of some length.

6. *Brake Applies Quick Action.*—If a brake applies quick action during a service reduction, it may be due to the packing ring in the vent piston *129* fitting its cylinder too tightly, to a weak vent-valve spring *132*, or to the small port *F* in the vent-valve piston being filled up, the port being plugged probably when the valve was last cleaned, due to carelessness on the part of the cleaner.

7. *Brake Fails to Apply Quick Action.*—Should the emergency action not take place when wanted, the vent-valve piston packing ring may be a poor fit or else badly worn.

23. *Blow at Triple Exhaust.*—If a blow occurs at the triple exhaust port, it may be caused by any of the following: A leaky exhaust valve; a leaky graduating valve; a defective gasket between triple body and brake-cylinder head in passenger equipment, or the gasket between the triple and auxiliary in the freight equipment, if the pipe *b* in the freight equipment, leading from the triple to the brake cylinder, is leaking.

In every case except the first, the leak allows air to reach the brake cylinder and pass through the exhaust cavity *h* in the

exhaust valve and thence out through port *T* and the triple exhaust port to the atmosphere, when the triple is in release position; but when the brake is applied, the exhaust port is closed and the blow does not occur at the exhaust. In this case, the air continuing to leak into the brake cylinder applies the brake harder. If auxiliary air leaks into the brake cylinder, the tendency will be to release the brake.

A *leaky exhaust valve* will generally cause a blow at the exhaust port of the triple, regardless of whether the exhaust valve is in service or in release position, since in either position auxiliary air can feed across the face of the valve into the exhaust cavity *h*, Fig. 8, and out through port *j* and the exhaust port to the atmosphere. With a leaking exhaust valve, the tendency for the brake when set is to release itself as auxiliary pressure is being reduced.

Of the possible leaks given, the one that is most likely to be the source of trouble is the exhaust valve.

Rubber-Seated Valves Leaking.—If rubber-seated vent valve *71*, Fig. 8, is leaking, a blow will be heard at the round port *M* whether the brake is set or not; if the rubber-seated emergency valve *138* leaks, there will be a blow at the two square ports *J* under piston *137* (shown in Figs. 8, 9, and 10); if valve *138* leaks badly, there may be a short blow at the triple exhaust port as well as the blow at the two square ports *J*; if check-valve *117* leaks, there will be a blow at the two square ports under piston *137* when the brake is applied, but not when it is released.

To remedy these troubles, tap the nuts *141*, *119*, and cap *126* lightly. This remedy failing, cut out the brake, bleed the air out of the auxiliary reservoir, and remove nut *141*, or cap *126*, as the case may require, and clean the seats if dirty, or renew them if worn out. To clean check-valve *117*, release the brake and unscrew nut *119*. It is not necessary to cut out the brake or bleed the auxiliary to clean the check-valve.

Leaky Exhaust Valve.—A leaky exhaust valve will cause a constant blow at the triple exhaust, which will allow auxiliary air to escape to the atmosphere across the face of the exhaust valve, and in some cases may release the brake after being

applied. A thorough inspection of the triple is the proper remedy for this defect, as the valve may need reseating.

Triple Freezing Up.—Water sometimes accumulates in the drain cup of the triple valves. In cold weather this water may freeze and cause trouble. In thawing out a triple, always remove the drain plug and drain off the water to avoid a recurrence of the trouble. The water found in the brake system comes from the moisture drawn into the pump with the air. After the air is compressed, this moisture is given up, and some of it works back into the brake system.

PLAIN TRIPLE VALVE.

24. The **plain triple valve,** Fig. 5, is found only on engines and tenders. The parts of this triple correspond to the service parts of the quick-action triple, and they are liable to the same disorders.

LEAKS AND OTHER DEFECTS.

25. Among the most common causes of trouble with the plain triple are: (1) leaky valves; (2) rings in bad order; (3) exhaust port blowing; and (4) triple freezing up.

1. *Leaky Valves.*—A leaky exhaust valve or graduating valve will affect the brake in the same manner as the same defect in a quick-action triple would.

2. *Defective Rings.*—A worn piston packing-ring *3*, Fig. 5, will allow air to feed by the piston, and may charge the auxiliary too quickly. On a long train, a slow train-pipe reduction might allow auxiliary air to feed back through the feed grooves *b* and *m* and by the packing ring sufficiently fast to keep equal with train-pipe pressure, in which case the triple piston would not be forced out and the brake would not apply; or, in releasing brakes, if train-pipe pressure is increased slowly, air might feed by the packing ring sufficiently fast to charge the auxiliary and leave the brake set.

3. *Triple Exhaust Blowing.*—A blow at the exhaust port may be caused by a leaky exhaust valve *38* or graduating valve *48*.

As in the case of the quick-action triple, there will be a continuous blow at the exhaust port if the exhaust valve leaks, regardless of whether the brake is applied or released.

4. *Triple Freezing Up.*—Water may collect in chamber *G*, and the latter should therefore be drained occasionally by partially unscrewing the plug *13*.

CARE OF TRIPLES.

CLEANING.

26. Triple valves should be inspected and thoroughly cleaned and oiled as often as necessary. In cleaning the triple, it is a good idea to immerse the triple piston in benzine or kerosene while cleaning the other parts. The emergency parts of the quick-action triple should be removed, examined, carefully cleaned, and then replaced without oiling, as these particular parts are seldom used, and oil would only serve to collect dirt. The graduating valve and exhaust valve, and the chamber in which they work, should be thoroughly cleaned, and great care should be exercised to remove any lint from the valves or their seats. All ports should be carefully cleaned, particular attention being given to the feed groove. After everything else has been attended to, the triple piston packing ring and vent-valve piston packing ring should be cleaned carefully *without removing them from the pistons*, as in removing them you are sure to spring the rings out of true. Before replacing the piston, the ring should move freely to the touch, and in entering the piston into its bushing, care should be taken not to bruise the packing ring.

OILING.

27. The only parts of the triple that need oiling are the triple piston packing ring and the bushing in which it works, the face of the exhaust and graduating valves, and the vent-valve cylinder and piston packing-ring. Too much oil is a detriment rather than a benefit, as it collects scale and dirt.

The strainer in the triple should always be cleaned. When oiling a triple, care should be taken to examine all springs and valves, and the stems should be examined to see that none are bent so as to bind. Also, the condition of the gaskets should be observed, and it should be ascertained whether all the valve seats fit tight, especially the check-valve *117*, as any leakage past this valve will cause a loss of brake-cylinder pressure for that brake. Also, see that all the parts move freely, and that the cap nuts do not leak.

FREIGHT EQUIPMENT.

LEAKS AND OTHER DEFECTS.

28. In addition to the causes of trouble already given as occurring in the triple itself, there are other defects to which the **freight equipment** shown in Fig. 11 is liable. The trouble may arise from one or more of the following:

Defective Gasket.—The gasket *15* between the triple valve and the auxiliary may leak, allowing air to pass from the auxiliary into pipe *b*, and to the brake cylinder; or, from the auxiliary to the atmosphere. The leak between the auxiliary and the brake cylinder will cause a blow at the triple exhaust port when the triple is in release position. After the brake is applied and the triple is in service position, however, the leakage of auxiliary air across the gasket, either to the brake cylinder or to the atmosphere, will tend to release the brake.

Pipe Leaking in Auxiliary.—If pipe *b* leaks inside of the auxiliary, the same effect will be noticed as if the gasket *15* leaked between the auxiliary and pipe *b*. Also, the core plug in the end of the auxiliary reservoir may leak, or there may be a sand hole in the auxiliary.

Leaky Valves.—A leaky release valve *17* will allow a constant escape of auxiliary pressure to the atmosphere. With the triple valve in release position, the pump will supply this leak and no ill effect will be noticed, aside from the extra work put upon the pump; when the brake is applied,

however, the escape of auxiliary pressure to the atmosphere will tend to release it.

The sleeve *3* sometimes splits, owing to the side motion of the push rod that works inside it. When this occurs, the release spring cannot force the brake piston to release position when brakes are released, as it binds in the hood of the cylinder; consequently, the brake shoes tend to drag on the wheels.

Defective Spring.—If the release spring *9* is weak, it will not force the brake piston to release position properly, especially if the cylinder is somewhat dirty; as a result of this, the piston may stay out after the triple has moved to release position and allowed the air to escape from the cylinder. In such a case, the sleeve and piston may gradually work in when the car is moving, as the jar of the wheels against the shoes may work them away, and cause the rods and levers to assume their normal release positions.

Defective Packing.—If the packing leather *7* is improperly fitted, or cracked or worn through on the bend of the flange, it will be impossible to keep that brake on, for as the air enters the cylinder, it will escape by the piston, and the brake will gradually leak off. Sometimes a brake in this condition will not apply with a service application, but will do so with an emergency application, after which it leaks off.

If the leakage groove *a* of a brake becomes stopped up with dirt or gum, and the brake is near the rear end of a long train, the train pipe of which leaks, the reduction due to the leak may work the triple piston out far enough to close the exhaust port and allow some of the auxiliary-reservoir air to reach the brake cylinder. The air feeding in slowly would pass through the leakage groove were it open; but, being closed, the brake on this car will gradually apply and might stall the train.

Expander Ring Out of Place.—The duty of the expander ring *8* is to hold the flange of the packing leather against the walls of the cylinder. If the expander ring works out, due to its not being put in properly, the flange of the leather would drop down, and all air entering the cylinder would probably escape past the piston to the atmosphere. Also, the nuts, if

improperly tightened, may work off the follower-plate studs and allow the follower plate to become loose, or the gasket between the cylinder and cylinder head may be blown out or leaking.

CARE OF EQUIPMENT.

29. Cleaning and Oiling Cylinder.—When the cylinder head and piston are removed, the walls of the cylinder should be thoroughly cleaned with waste saturated with kerosene, and special care should be exercised to free the leakage groove of all dirt or gum; the cylinder should then be wiped dry.

The expander ring should be removed and thoroughly cleaned, together with the groove in which the ring rests. The packing leather should be removed and carefully examined, and if it is in good condition it should be softened with oil or grease and replaced, being careful to get it on the piston properly; then replace the follower plate and tighten it up. Before the expander ring is replaced, a small amount of oil or grease should be put into the groove. Before replacing the piston, the cylinder should be thoroughly oiled or greased by rubbing the walls with the hand covered with oil or grease. When the cylinder is oiled through the oil plug *16*, care should be taken not to put in so much that, when the piston is moved to release position, the oil will be forced through pipe *b* into the triple exhaust and cause trouble. However, on new equipment this oil plug is being omitted, so that the cylinder must be taken apart for oiling, which is then more liable to be properly done.

30. Cleaning and Oiling Triples.—In cleaning and oiling the triple, all parts should be thoroughly cleaned. It is not necessary to oil the emergency parts, and care should be taken to properly oil the exhaust and graduating valves, their bushing, the triple piston packing ring, and the bushing in which it works. The strainer, where the branch pipe couples to the triple, and those in the drain cups should also be cleaned.

RETAINING VALVE.

DUTIES OF THIS VALVE.

31. The primary object of the **retaining valve** is to retain a pressure of 15 pounds in the brake cylinder during the time the triple is in release position and the engineer is recharging the auxiliaries while descending a grade. It has no effect whatever on any brake except that of the car on which it is placed, and it only affects the releasing of that brake, since it merely retains 15 pounds pressure in the brake cylinder.

The retainers often perform another duty, however, namely, to keep the slack of a freight train bunched after brakes have been released, and the train is drifting preparatory to making a stop. Two or three of the head-end retainers judiciously used in such a case will often prevent a bad jar at the rear of a train.

The retainer is used on almost all cars in freight service, and in mountainous districts, on passenger cars also. A modern retainer when in service holds 15 pounds pressure in the brake cylinder while the triple is in release, regardless of whether the piston travel is long or short.

To test a retaining valve on the road, the handle should be turned up and the engineer then signaled to apply and release the brakes. Shortly after air ceases to discharge from the retainer, turn down the handle, and if air again discharges, the retainer may be considered to be all right.

32. Use on Grades.—In using the retaining valves on a grade, it is best not to raise the handles until the train is rounding the summit of the hill. If the retaining handles are turned up before the summit is reached, and the leakage groove in any of the brake cylinders should be stopped up, any leak that would allow air pressure to reach that cylinder would set the brake, and perhaps stall the train.

GAINS DUE TO ITS USE.

33. The following will give an idea of the aid gained by using the retaining valve in handling trains on grades:

With train pipe and auxiliary fully charged, and the piston

travel adjusted to 8 inches, a 5-pound train-pipe reduction will give a brake-cylinder pressure of about 10 pounds; with this brake full set, a pressure of about 50½ pounds is developed in the brake cylinder. If the retaining-valve handle is now raised and train-pipe pressure increased so as to force the triple-valve piston to release position, the auxiliary will be recharged to 70 pounds, *while the brake cylinder will retain 15 pounds.* This will cause the brake cylinder and auxiliary to equalize at about 56 pounds, instead of 50, on succeeding applications as long as the retaining valve is cut in. This not only gives a greater braking power, but also saves air, since a reduction of only about 15 pounds is necessary to make a full application of the brakes. Then again, with 15 pounds already in the brake cylinder, a 5-pound reduction will give a brake-cylinder pressure of about 38 pounds. It is thus seen that by using retainers a large gain in braking power is made with the first 5-pound reduction, a gain is made when the brake is full set, less air need be wasted to apply the brake in full, and less time is required to recharge after a release is made.

The gain made with a 5-pound train-pipe reduction, after the retaining valve is cut in, appears, at first glance, to be out of proportion, but it should be remembered that, when the retaining valve is not in use and a train-pipe reduction is made, part of the first auxiliary air that enters the brake cylinder escapes through the leakage groove to the atmosphere before the piston has moved out far enough to close it. This loss does not occur when the retaining valve is in use, as the 15 pounds retained by it holds the piston out far enough to cover the leakage groove; also, it holds the flanges of the packing leather against the cylinder walls.

It will thus be seen that a retaining valve is not only an aid in controlling the speed of the train while on a down grade, during the time the pump is recharging the auxiliaries, but it is an adjunct that causes a more powerful braking power to be developed while in use.

LEAKS AND DEFECTS.

34. The retaining valve, Fig. 13, will be rendered less efficient by any of the following defects: (1) A leaky plug cock *6*, which will allow the pressure that should be retained in the brake cylinder to leak by the plug valve into port *e*, and thence to the atmosphere. (2) By dirt on the seat of the weighted valve *4*, which will hold the valve from its seat and allow the air to pass by the valve and out to the atmosphere at port *d*. (3) A leak at the retainer-pipe union, which also allows the brake-cylinder pressure to escape to the atmosphere. (4) A split in the pipe leading to the retaining valve, or a leaky packing leather in the brake cylinder, will produce the same effect as an imperfect retaining valve. (5) If port *d* is stopped up, all the air will be retained in the brake cylinder when the brakes are released; consequently, the brake will remain set.

At such times as the triple on a car is being cleaned and repaired, the retainer should be cleaned also; the cap nut should be removed and the valve and its seat cleaned. Also, the retainer pipe should be tested with soapsuds for leaks.

BRAKE VALVE.

DEFECTS.

35. Testing Excess-Pressure Spring.—If the pump is started with the brake valve in full release, both red and black gauge hands should move up together, as, in this position, main-reservoir and train-pipe pressures are directly connected. If the gauge hands do not stay together, the gauge is incorrect, and should be reported for adjustment. With this valve, the pump governor is operated by train-pipe pressure; consequently, it stops the pump when train-pipe pressure reaches 70 pounds, and with the brake valve in release position, both hands of the gauge should register this amount when the pump stops.

If the pump is started with the valve handle in *running* position, the red hand should be 20 pounds in advance of the

black one; and when the pump stops, the black hand should register 70 and the red hand 90 pounds. If the black hand indicates 70 pounds, but the red hand indicates less than 90, the excess-pressure spring *90*, Fig. 19, is either too short or too weak.

If the black hand stands at 70 pounds and the red above 90, the excess-pressure spring is too stiff, or the valve *97* needs cleaning to make it work more freely.

Should the spring *90* break, lengthen the longer piece, by stretching, until it will hold the excess-pressure valve to its seat with sufficient force to maintain, as nearly as possible, the proper excess pressure. If the spring breaks near the middle, it may be necessary to force a small piece of wood into the cap nut *98* so as to partially fill it and thus compensate for the short spring. The broken spring should be replàced by a new one at the first opportunity.

If the spring is too weak, it should be removed and lengthened, by stretching, until of the proper strength, or else a washer should be placed in the valve behind the spring; if the spring is too stiff, it should be replaced by one of proper tension or else a piece may be cut off one end and the spring used that way until it can be replaced with a new one.

If, when the pump stops, the black hand registers either more or less than 70 pounds, and the red hand shows that the proper excess pressure is maintained, then the pump governor needs adjusting. To do this, remove the cap nut *7*, Fig. 3, slack nut *9*, and unscrew the regulating screw *8*, to adjust for a lower train-pipe pressure, or screw it down for a higher pressure.

36. Brake Valve Fails to Maintain Excess Pressure. If, with the valve in running position, both hands remain together all the time, and no excess pressure is maintained, the trouble is caused by a leaky main slide valve or by dirt on the seat of the excess-pressure valve *97*, Fig. 19. Sometimes this leak from the main reservoir into the train pipe is so slight that it does not affect the excess pressure when the engine is coupled to a train; but, with the engine alone, no excess pressure can be maintained, as the train-pipe pressure

equalizes with the main-reservoir pressure. In the former case, leaks out of the train pipe compensate for the slight leak into it; while, in the latter, the train pipe is so short that practically no air leaks out, in which case the leak into it soon causes the train pipe and main reservoir to equalize.

37. To test for a leaky main slide valve, close the cut-out cock below the brake valve, place the valve handle in lap position, and start the pump. In lap position, all ports are blanked and any leak into the train pipe will be indicated by the black hand of the air gauge.

Another method of testing the main slide valve, when the brake system is charged, is to make a service reduction of 10 or 15 pounds, then close the cut-out cock in the train pipe underneath the valve, and place the brake-valve handle on lap. If any leakage of main-reservoir air occurs past the main slide valve into the train pipe, it will be indicated by an increase of train-pipe pressure, and the black hand of the air gauge will rise.

Still another method, when the brake system is charged, is to place the brake-valve handle in the first or second graduating notch of the service position. If the escape of air at the exhaust passage *C* does not entirely stop, but continues to escape, and, at the same time, the black hand of air gauge does not fall, it is proof that main-reservoir air is leaking through the main slide valve into the train pipe.

EXCESS-PRESSURE VALVE FAULTS.

38. If the main slide valve does not leak, the trouble must be in the excess-pressure valve. In fact, dirt on the seat of the excess-pressure valve is generally found to be the source of trouble when excess pressure cannot be maintained.

39. If necessary to remove the excess-pressure valve *97*, for cleaning or otherwise, close the cut-out cock *9*, Fig. 1, under the brake valve, stop the pump, bleed the main reservoir, and place the brake valve in emergency position before attempting to remove it. Closing the cut-out cock retains the

air in the train pipe and auxiliaries, while placing the brake valve in emergency position empties the train pipe above the cut-out cock *9*, thus removing all pressure from the excess-pressure valve. The valve may then be removed by unscrewing the cap nut *98*. *Clean both the valve and its seat thoroughly*, being careful not to scrape the face or seat of the valve with any hard material.

40. **Occasionally the excess-pressure valve becomes stuck shut** so that air cannot pass into the train pipe through it when the brake valve is placed in running position. This results usually from the use of too much or poor oil in the air end of the pump; the oil forms a gum that gradually blocks the excess-pressure valve, and may cause trouble in other parts of the air-brake system. With the excess-pressure valve stuck, the engineer very often goes over the road with the brake-valve handle in full release, and with no excess pressure. If the excess-pressure valve sticks, take it out and clean it. The best time to clean the excess-pressure valve is just before starting the pump. This can be done in a few minutes, and will cause very much less delay than if it were allowed to remain stuck and the valve carried in full release, as in the latter case the brakes are liable to stick after each application. If the excess-pressure valve *97 works stiffly* in the cap nut *98*, Fig. 19, the valve will be less sensitive than usual and the excess pressure will fluctuate. That is, when the valve works stiffly, more than 20 pounds excess pressure must be obtained before it will open, while, on the other hand, it will not close until the excess pressure is less than 20 pounds.

41. **A leak in the main slide valve or past the excess-pressure valve** that will allow train-pipe and main-reservoir pressures to equalize will maintain them equal, and since, with this brake valve, the governor is set to stop the pump as soon as a train-pipe pressure of 70 pounds is obtained, the pump will not start again until the pressure in both train pipe and main reservoir is reduced to that amount. If this reduction is brought about by leakage, it is very liable to cause the brakes to "creep on."

CARE OF ENGINEER'S VALVE.

42. Lubricating the Valve.—There is a wide range of variation in the time a main slide valve will continue working satisfactorily in general service. Some valves will run three, four, or six months, depending on the care they receive.

Tallow or *vaseline* are good lubricants for the main slide valve, but oil of any kind should be used sparingly on any part of the brake apparatus except the steam end of the pump. Oil that has a tendency to gum should never be used.

Whenever the main slide valve works hard, the oil plugs *96*, Fig. 20, on top of the brake valve should be removed, and two or three drops of good oil poured into each oil hole, the handle of the brake valve being moved from one extreme position to the other so that the oil can be dropped on to each end of the valve seat. A little oil should be dropped into the oil hole *h*, Fig. 19, over the handle shaft, to lubricate the shaft *120*. The valve should be taken apart occasionally and thoroughly cleaned.

43. The chief causes of a main slide valve working hard are: too free use of oil in the air end of the pump, or the use of poor oil; a hot pump, the heat from which will cake the oil on the main slide-valve seat. Sometimes lack of oil on shaft *120*, Fig. 19, will have the same effect as a dry main slide valve.

44. In cleaning the excess-pressure valve, remove all dirt and gum and clean the valve chambers thoroughly. Any gum found should be softened, if possible, and wiped out instead of scraping out with a tool that is liable to scratch the valve seat.

SUPPLEMENTARY RESERVOIR.

45. The supplementary reservoir plays a very important part in the handling of the brakes in service applications. The duty of this reservoir is to hold the air used to move the equalizing piston and cut-off valve, and automatically lap the valve in service reductions. A slight leak in the supplementary reservoir, or from chamber *D* past the gasket that is

between the brake-valve body and back cap, or from the reservoir connections, would destroy this feature and make it necessary to lap the valve by hand. With such a leak, carry the brake valve in release position to cut out the leak; also, in making a service stop, carry the valve handle midway between lap and first graduating notches between reductions.

DEFECTS OF ENGINEER'S VALVE.

46. Should the main slide valve *114*, Fig. 19, of the engineer's valve allow main-reservoir pressure to pass into chamber *A* and the train pipe, it would be impossible to obtain any excess pressure with the handle of the brake valve in running position.

Should this leakage occur with the brake valve in service position, it may raise the train-pipe pressure sufficiently to move the piston toward chamber *D* and cause the cut-off valve to reopen the discharge port, the train-pipe pressure will then be reduced sufficiently to cause chamber *D* pressure to again move the piston forwards and make the cut-off valve close the discharge port.

If a leak past the excess-pressure valve *97*, Fig. 19, is greater than the vent port *e* in the pump governor, Fig. 3, can accommodate, it will prevent any excess pressure being accumulated in the main reservoir, in either running or lap position.

The excess-pressure valve in the brake valve controls the flow of air between the main reservoir and train pipe, when the handle is in running position, and the tension of the excess-pressure spring determines the amount of excess pressure carried in the main reservoir. Any leakage, therefore, either on account of dirt getting under the valve, or its seat or face being defective, will destroy the efficiency of the valve.

Leaks in the supplementary reservoir, its connections, or in the packing leather *107*, Fig. 20, of the equalizing piston, or gasket *R* between the back cap and the body of the valve, all have the same effect—namely, to destroy the automatic lapping feature of the brake valve in service applications. Also, any wear in the pivot pins, or the pins that engage the slots of the

lever and link, interferes with the automatic lapping of the cut-off valve. Should the cut-off valve *110* leak, it would allow train-pipe pressure to continue to reduce through the service ports in main slide valve, when the handle is in service position, and would apply the brake harder than intended.

To test for leaky packing ring in piston 104, close the cut-out cock underneath the brake valve, place the valve on lap, and start the pump. When full main-reservoir pressure has been obtained, and no leakage through main slide is observed, place the valve handle in running position, and charge the train pipe and supplementary reservoir; next, move valve handle to emergency position, and, after train pipe is empty, move it back to first or second graduating notch, when any leakage from the supplementary reservoir past the equalizing piston will be indicated by a rise of the black hand on the air gauge.

The equalizing piston, supplementary reservoir and its connections being tight, to test for a leaky cut-off valve *110*, place the brake-valve handle in service position, and if the exhaust from the train pipe does not stop when it should, but continues to drag out until the train pipe is empty, the cut-off valve is leaking.

Sometimes, in making a second application immediately after releasing the brakes without recharging, it is found that a reduction cannot be made from the first graduating notches, but that when the valve handle is moved several notches toward full application, the reduction can be made. This is due to the fact that in releasing, the brake valve was not left in release position long enough for supplementary-reservoir pressure to be reduced sufficiently to move the piston back to its normal position; consequently, it is left standing near the middle of the cylinder and the brake-valve handle has to be moved several notches toward full-application position to open the discharge valve. In releasing brakes, the brake-valve handle should always be left in release position long enough to permit of sufficient air being discharged from the supplementary reservoir to cause the piston *104* to move back to its normal position.

THE NEW YORK AIR BRAKE.

(PART 3.)

OPERATING AND TESTING.

THE MAKE-UP OF A TRAIN.

1. The smoothness and ease with which a freight train can be handled, as well as the facility with which it can be stopped by means of the air brake, depends, to a considerable extent, on the way the train is made up. The make-up of a passenger train, on the other hand, affects the handling of the train so very slightly that, so far as the braking is concerned, no particular attention need be paid to it.

GENERAL CONSIDERATIONS.

2. The conditions of braking on passenger and freight trains differ greatly. On a passenger train there is no free slack between cars to bother us; both the load and the braking power are distributed quite uniformly throughout the length of the train; the brakes are kept in good condition, and the piston travel is maintained within proper limits; train-pipe, auxiliary, and brake-cylinder leakage is very slight; and the length of the train pipe is such that, practically, the brakes set simultaneously on all parts of the train.

With a freight train, on the other hand, there is a great deal of slack, which must be handled properly to avoid severe shocks; the load is generally distributed unevenly throughout the train; the brakes generally do not receive sufficient attention to keep them in as good condition as those on a passenger train; and the brake-piston travel is seldom uniform.

Consequently, the braking force, even on an "all-air" train, is not uniform throughout its length; the leakage in the brake system is greater in freight than in passenger service; and, lastly, the train pipe on a freight train is generally so long that the retarding effect of friction on the flow of air through it is sufficient to cause an appreciable interval of time to elapse between the operation of the first and last brakes.

3. Effects of Slack.—There is always a great deal of free slack in a freight train, and it must be handled with great care or else severe shocks will result, which may injure both draw-bars and freight. The slack is less troublesome on all-air than on part-air trains, since in the former each car is equipped with the air brake, which permits of the retarding force being applied to, or removed from, each car at nearly the same instant; the slack, therefore, cannot gather or run out quickly, and shocks, when they occur, are less severe. However, a large number of freight trains are in operation that have only a part of the cars equipped with air brakes, and with these the effect of slack is most severe.

The engineer has more or less direct control over the slack that is between the air cars, but he has no control over that between the non-air cars; consequently, the free slack back of the air cars must be "taken up" every time the brakes are applied, and be run out at every release. Whether a shock will occur either in "bunching" or "stretching" a train, depends on how quickly it is accomplished. If the first service reduction is made sufficiently heavy to bunch the train quickly, the last cars will run up against the others with great force; and the heavier the last cars are loaded, the greater will be the shock and consequent damage. On the other hand, the lighter the rear cars, the less the shock; hence, a part-air train can be handled more easily, and with less chance of damage to freight, if the heavily loaded cars are placed next to the air cars, and the less heavily loaded ones and empties, next to the way car.

4. Effects of Unevenly Distributed Load.—When a freight train is made up of both loaded and empty cars, and the loaded cars are distributed haphazard throughout the train,

the load is said to be distributed unevenly. Since it is harder both to start and stop loaded cars, shocks of a more or less serious nature occur at different points of the train every time it is started, stopped, or has its speed retarded suddenly. This trouble can be avoided by placing all loaded cars together at the head end of the train.

5. Effects of Unequal Piston Travel.—To effect smooth handling of freight trains by means of the air brake, it is essential that the travel of the brake-cylinder pistons be kept within the proper limits. If the piston travel on some of the cars in a train is too short, while on others it is too long, shocks will occur at a number of points in the train every time the brakes are applied or released. This is due to the fact that the brake cylinders having a short piston travel apply their brakes harder at each reduction and equalize with their auxiliaries sooner, and at a higher pressure, than those having a long piston travel; also, they release later than the long-travel brakes. This causes the slack to be gathered at some parts of the train, and to run out at others, every time the brakes are applied or released, producing a surging of the cars that results in shocks which make smooth handling of the train difficult.

6. Effects of Length of Train Pipe.—The length of the train pipe also has considerable influence on the ease with which the train can be handled. The friction of the air tends to retard its flow through the train pipe, and the longer the train pipe, the more troublesome this retarding effect becomes. When conditions are normal, the retarding effect is such that in making an ordinary service reduction on a fifty-car air freight train, the pressure in the head end of the train pipe is reduced about 6 pounds before the reduction begins to be felt at the rear end; while, on releasing brakes on such a train, there may be a difference of pressure of about 10 or 12 pounds between the two ends, the pressure at the head end being the higher. This difference of pressure causes the head-end brakes to both apply and release sooner than the rear-end ones, with the result that, on a long train, some severe shocks will be produced if the brakes are not handled with skill and judgment.

MAKING UP A TRAIN.

ALL-AIR TRAIN.

7. All-air freight trains could be handled much more smoothly and satisfactorily if all the loaded cars were placed next to the engine, and the empties next to the way car. Also, when the cars are mostly equipped with quick-action triples, care should be taken not to place two or three cars together that either have plain triples, or have their brakes cut out, or are merely piped, since, in cases of emergency, it will be impossible to obtain the quick action of the triples back of them.

PART-AIR TRAIN.

8. In making up a **part-air train,** all the air cars, whether loaded or empty, should be placed together at the head end of the train and cut into service. Every air brake possible should be employed in braking, since the more in use the more smoothly the train can be handled; besides, they may be needed to make a quick stop in an emergency. Do not place together three or four cars with plain triples, or with brakes cut out, if most of the cars have quick-action triples, but distribute them among the quick-action cars. As to the non-air cars, the best results will be obtained if they can be so arranged that the loaded ones are next to the air cars and ahead of the empties.

TESTING BRAKES.

ENGINE EQUIPMENT.

9. Air Pump.—Any defects in the engine air-brake or signal apparatus should be reported at the end of the trip, so that the necessary repairs can be made before the engine is again called into service. If necessary, tests should be made to locate the defects.

The air pump should be tested under its usual head of steam as follows: With the pump running at normal speed, note the

time at intervals of 10 pounds, while the main-reservoir pressure is being raised from 40 to 90 pounds. If the pressure is pumped in the usual time, during which the pump shows no sign of disorder, the presumption is that it is in good condition and no further tests will be necessary. If, on the other hand, the test shows that the pump is not in its normal condition, the trouble may be due to (1) leaky piston packing-rings; (2) receiving valves leaking; (3) back leakage from main reservoir; or (4) the air valves may be stuck. Tests, as in Art. **12,** Part 2, should be made to locate the cause.

10. Pump Governor.—The pump governor should be tested to see whether standard pressure is obtained when it stops the pump, also to see whether it will start the pump promptly when a light reduction of not more than 2 pounds is made in the pressure that operates the governor (see Art. **24,** Part 1). If the pump stops either before or after standard pressure is obtained, the governor should be adjusted, by means of the adjusting screw *8*, until it regulates the pump properly (see Art. **35,** Part 2). If the governor does not start the pump promptly when a slight reduction is made, it may be due to a leaky diaphragm valve or to the relief port *e* being stopped up.

11. Brake Valve.—The brake valve should be tested for leaks from the main reservoir into the train pipe. This can occur only through the main slide valve, so that a test for a leaky main slide valve should be made according to the method given in Art. **37,** Part 2. Next, the excess-pressure valve should be tested to see if it is tight, and the excess-pressure spring to see if it has the proper tension. The excess-pressure valve and spring may be tested according to the method described in Art. **35,** Part 2.

It is important that the equalizing piston be absolutely tight, and also all the connections leading from the brake valve to the supplementary reservoir. All connections being tight, the packing in the equalizing piston may be tested by the method given in Art. **46,** Part 2. The small cut-off valve should be tested, Art. **46,** to know that it is tight.

12. Driver and Tender Brakes.—An air gauge should be attached to the driver- and tender-brake cylinders at least once a month, to ascertain the condition of the piston packing leathers. After the auxiliaries are fully charged, make a 35- or 40-pound service reduction, lap the valve, and note the pressure at which the auxiliary and brake cylinders equalize. Also, note the pressure at the end of 5 minutes; if it does not decrease more than 5 or 6 pounds during that time, the brake cylinder is in good condition. If the gauge shows that the brake-cylinder pressure decreases at a considerably greater rate, examine the packing leathers and look for leaks in the cylinder connections, the gasket between the cylinder and head, and the piston-rod packing.

If the driver-brake cylinder is in such a position that it is subjected to considerable heat, it should be oiled sufficiently often to keep the packing leather soft and pliable. It is poor practice to use water to soften the packing leather, since it dries out very quickly and the leather then becomes harder and is much more liable to crack.

Driver Brake Fails to Apply.—If the driver brake fails to apply, first see whether the handle of the cut-out cock is turned so as to cut out the brake. The brake being cut in, open the release cock on the auxiliary to see whether it is charged. If the discharge indicates that the auxiliary is charged, it may be that the triple piston, being badly gummed, is stuck in the release position, or that its packing ring is badly worn. In either case, when a reduction is made, the auxiliary may equalize with the train pipe through the feed groove and past the packing ring so fast that the piston is not moved out. In case the triple piston is stuck, one or two sudden, heavy reductions should loosen it. If the cause cannot be located, take down the triple and examine it. Also examine the brake-cylinder packing leathers.

Driver Brake Fails to Release.—This may be due to worn packing rings in the triple valve, aided by dirt and gum, the leakage past the triple piston ring allowing auxiliary pressure to equalize with the train pipe without moving the triple piston; or the triple exhaust port may be stopped up; or the release

spring in the brake cylinder may be weak or broken; or, in the cam-brake, the piston travel may be so long that the brakes lock against the drivers. In the latter event, the cams must be pried until the brake releases. In the event of the brake being stuck, try to release it by making a heavy reduction and then quickly placing the brake valve in full-release position.

Driver Brake Releases.—If the driver brakes release soon after being applied, it may be due to a leak in the auxiliary reservoir or its connection, to a leaky graduating valve in the triple valve, or to a leak in the piston packing leather or piston-rod packing.

13. Triple Valves.—Plain triples are used on the engine and tender; therefore, if a blow occurs at the exhaust port of either triple, look for a leaky exhaust valve *38* or leaky graduating valve *48*. To determine which of these is causing the blow, apply the brake lightly; this causes the exhaust valve to close communication between port *j* and the exhaust port *i*, and if the trouble is due to a leaky graduating valve, the blow will cease, while if due to a leaky exhaust valve, it will continue.

The method of testing the air-signal system for defects will be given after the signal system has been explained.

TERMINAL TEST OF TRAIN.

14. General Instructions.—If possible, all the air cars should be coupled up and the brakes cut in before the engine is connected to the train, as both time and air can be saved by so doing.

On taking his engine, the engineer should start his pump and run it slowly until sufficient pressure is accumulated in the main reservoir to properly cushion the pump; he should then increase its speed and pump up the proper main-reservoir pressure. Also, he should carefully inspect the air-brake apparatus on both the engine and tender, to assure himself that all necessary repairs have been made, and that everything is in perfect working order. The train pipe on the engine should be blown out to get rid of any dirt and water there may be in it,

before the engine is coupled to the train. The brake valve should be carried in lap position* while the engine is being coupled to the train. After coupling the hose between engine and tender, the tender angle cock should be opened first, so that the hose will be charged from the engine before the car angle cock is opened. If the car angle cock is opened first and the train is short and equipped with quick-action triples, the brakes are liable to apply quick action, due to the sudden reduction caused by train-pipe air expanding to fill the empty hose. The angle cocks should always be opened slowly, since, if the handle is turned quickly, emergency action may result.

During the time the train is being charged, the inspector or trainman, as the case may be, should pass along and examine each car for leaks and other defects. It should be observed whether all the angle cocks are open, except the rear one on the last air-brake car; whether the cock in each branch pipe is open so that all the cars, except those that are not in good condition, are cut in; whether the hand-brakes are fully released; and, if the retainers are to be used, whether the retainer handles are turned up.

After the train has been fully charged to standard pressure, the brake system should be tested. If time will permit, 70 pounds pressure should always be obtained before this test is made; but in no case should it be made with less than 60 pounds for passenger trains or 50 pounds for freight trains. When the train is fully charged, it will be indicated by the pump slowing up.

To make the test, a service reduction of from 5 to 7 pounds, or one just sufficient to move the brake pistons out past the leakage grooves, should be made, and the brake valve lapped. The engineer should then watch the air gauge to ascertain the extent of train-pipe leaks, since they will be indicated by the black hand falling. A sufficient number of moderate service reductions should then be made to produce a 20-pound train-pipe reduction, and the brakes should then be held on while

*There is considerable difference of opinion as to the position in which the valve should be carried when coupling to the train, but the consensus of opinion seems to favor lap position.

the train is inspected to see whether all brakes set or whether any of them leak off after being set; also, the length of the piston travel on each car should be examined. After the entire train has been inspected, the engineer should be signaled to release brakes, and if the train is equipped with the air-signal system, the signal should be given from the rear car, to make sure that the air signal is connected up and working properly. The engineer should then release the brakes, and if the retainers were not in use, the train should again be inspected to see whether all brakes release properly and whether there is a blow at the exhaust port of any of the triple valves. If the retainer handles were turned up during the test, the inspector or brakeman should go over the train after the engineer has released the brakes and turn the retainer handles down, noting, as he turns each down, whether the brake releases, and whether a blow occurs at retainer after brake has released. If air discharges from the retainer as the handle is turned down, the retainer is working properly. After the test, a report should be made to both the engineer and conductor, showing the total number of air and non-air cars in the train; the number of air cars in good working order and the number cut out; the condition of the piston travel; the number of retainers, if they are to be used, that are working properly; and also the general condition of the train.

In making the first service reduction in testing the brakes, the engineer should note the length of time the train-pipe exhaust blows, as by making a practice of so doing, he soon will be able to judge the length of train pipe that is cut in, and thus, in many instances, can detect an angle cock that has been left closed.

15. Brake Fails to Apply.—If, during the inspection, a brake is found that will not set, first make sure that it is cut in, and then try the bleed cock on the auxiliary reservoir to ascertain whether the reservoir has been charged. If the auxiliary is not charged, take the triple down and look for a stopped-up feed groove. If air issues freely from the bleed cock, it may be that the feed groove was only partially stopped up, resulting

in the auxiliary being charged insufficiently to set the brake when the test was made. If the trouble cannot be remedied at the time, cut out the brake by closing the cut-out cock in the branch pipe leading to the triple.

16. Brake Releases.—If a certain brake will not stay on, but releases as soon as it is set, the trouble is due to a heavy leak either from the brake cylinder or from the auxiliary reservoir.

The leak from the brake cylinder may occur through the leakage groove or past the piston in the brake cylinder. The hand-brake on coach equipment may be set, or the slack in the brake may be taken up so short that the brake-cylinder piston cannot move out far enough to cover the leakage groove, in which case the brake will either not set, or will release at once. The leak past the brake-cylinder piston may be due to a dried-out packing leather, or to the expander ring being out of place.

Leaks from the auxiliary reservoir may occur through a defect in the release valve or through the triple exhaust port (see Arts. 20 and 23, Part 2). If at the release valve, look for a bent valve rod or for dirt on the valve seat. A leak due to the former may be remedied by straightening the valve rod; that due to the latter can in some cases be remedied by quickly jerking the release valve open two or three times. If the leak cannot be stopped, the brake must be cut out.

17. Brake Fails to Release.—If the brake refuses to release, first see if the handle of the retainer on that car is turned down, and if so, whether the retainer exhaust port is stopped up. A certain kind of wasp has been known, in some localities, to build its nest in the retainer and thus plug it up. The retainer being all right, see whether the hand-brake is fully released, whether the slack has been taken up too tight, or whether the brake has released, but the spring in the brake cylinder been unable to move the brake piston to release position. If the trouble is not in any of these places, it is pretty sure to be due to a badly worn packing ring in the triple-valve piston.

Testing Triple Piston.—The condition of the triple piston packing ring can be determined as follows: Apply the brake by making a 10- or 12-pound reduction, and then gradually open the release valve on the auxiliary of the defective brake a very small amount, so that a slight discharge takes place through it. If the brake does not release within 10 or 15 seconds, gradually open the release valve a little wider, so as to increase the rate of discharge. Continue to increase the discharge every 10 or 15 seconds, until the brake releases; then the rate at which air is escaping through the release valve will be a measure of the rate at which train-pipe air escapes past the triple piston packing ring. The escape of air through the release valve, however, must be slightly greater than that past the packing ring, as otherwise a sufficient auxiliary reduction could not be obtained to release the brake. When the packing ring is worn, train-pipe pressure must be increased quite rapidly to move the triple to release position; in such a case, therefore, the brakes are more liable to stick on a long, than on a short, train. After a light application on a very long train, some of the brakes on the rear of the train are liable to stick, although after a moderately heavy application they would release promptly on account of the greater excess pressure.

If the engineer finds that some of the brakes have a tendency to stick, he should carry the full amount of excess pressure all the time, and at places where a heavy application must be made, he should have a high main-reservoir pressure to insure prompt release and recharging.

18. Train-Pipe Leaks.—In inspecting a train for leaks, the parts to be inspected may be divided into (1) the train pipe and its branch pipes; (2) the hose and couplings; (3) the triple valves; (4) the auxiliary reservoir; and (5) the brake cylinder.

1. *The Train Pipe and Branch Pipes.*—Leaks in the train pipe may occur at any of the joints. If at the union joint at the car drain cup, it can sometimes be stopped by tightening that joint; if not, a new gasket must be used. When the leak occurs at the joint where the branch pipe screws into the car drain cup, or in the joints at the stop-cock in the branch pipe,

it can sometimes be stopped by disconnecting the branch pipe at the triple valve and turning the pipe until the leak ceases. If the leak occurs in the union at the triple, it may be stopped by tightening the union joint or by replacing the union gasket.

The leak may be due to a split or break in the train pipe. In that case, switch the car behind all the air cars and couple its hose to that of the last air car; then close the front angle cock on the defective car and open the rear one on the car ahead, so that the hose will be included in the train pipe. Then, should the train part between the defective car and the last air car, the brakes will be applied.

2. *The Hose and Couplings.*—In looking for leaks in an air-brake hose, not only the hose but also the couplings and nipples should be examined.

The hose itself may be porous, in which case the air escapes so silently and in such finely divided streams that it is very liable to be overlooked, especially as the hose may have the appearance of being perfectly sound. In some cases, such a hose can be detected by bringing a lighted torch near it, or by wetting the hand and moving it over the hose, the escaping air making the hand feel cooler. The best method, however, is to apply a little soap and water by means of a sponge or piece of waste; the escaping air will be indicated by the formation of bubbles. Such a hose, when located, should be removed and marked "defective," and a sound hose put in to replace it.

Leakage at the hose coupling may occur past the gaskets *2*, Fig. 10, Part 1, or under the hose clamps *c*. If in the gaskets, close the angle cocks on each side of the coupling, separate it, and if the gaskets have been distorted out of shape, straighten them out and try them again. If they still leak, new gaskets should be used. If none are at hand, separate the couplings and put a match or small sliver of wood back of each lug and again unite the couplings. This will force the gaskets closer together, and will probably stop the leak. Sometimes the manner in which frozen couplings are parted is the cause of trouble with coupling gaskets. Frozen couplings should always be thawed out before an attempt is made to part them, as otherwise the gaskets are almost sure to be ruined. Paper should

never be used between the hose gaskets to stop a leak, as it is very liable to work into the brake system and cause trouble. If the leak is under the hose clamp *c* and cannot be remedied by tightening the clamp, a new hose must be substituted.

Leakage at the hose nipple may be due to the nipple not being screwed into the angle cock tight enough, or the leak may occur under the nipple hose clamp. If the former, screw up the nipple until it makes a tight joint; if the latter, tighten the clamp, and if this does not stop the leak, change the hose.

3. *The Triple Valves.*—A blow at the triple exhaust port may be due to a leaky exhaust valve or graduating valve. To determine which valve is leaking, make a full-service application. If the exhaust valve leaks, the blow will continue; if it is the graduating valve that leaks, the blow will cease. If a blow occurs at the ports *M* or *J*, Fig. 9, under the emergency piston, it may come either from the auxiliary or train pipe. If the blow is from the train pipe, it can be felt at the round port *M*; if from the auxiliary, at the two square ports *J*. The exhaust port of the triple valve or of the pressure retainer must never be plugged up on account of a blow occurring at either place, for the reason that it would then be impossible to release the brake on that car.

4. *The Auxiliary Reservoir.*—Leakage from the auxiliary reservoir may occur through either the release valve or the triple exhaust port, as already mentioned.

5. *The Brake Cylinder.*—Brake-cylinder leakage was discussed in Art. 28, Part 2. If the leakage is very great, the brake should be cut out of service.

19. Cutting Out a Brake.—When, on account of some defect in the apparatus, it becomes absolutely necessary to cut a brake out of service, all that is necessary to do is to close the stop-cock in the branch pipe, or cross-over pipe, leading to the triple valve. The release valve of the auxiliary reservoir must then be opened, so that the reservoir will be relieved of all pressure; otherwise the brake is liable to set and cause trouble. Always cut the brake out on a car or engine, if the train pipe and auxiliary are charged while making repairs to the brake

rigging, to prevent injury in case of automatic application of the brakes, and do not forget to cut it in when the repairs are made. Never attempt to cut out a brake by closing the angle cocks at the ends of the car, as that will not only cut out the brake on that car, but on all others back of it, since closing an angle cock cuts off the train pipe back of it.

20. Cutting Out a Car.—A brake is cut out by closing the stop-cock in the branch pipe. A car is cut out by closing the angle cocks at each end of the car, the release valve being opened the same as when a brake is cut out. After a car has been cut out, it should be switched to the rear of the air cars, and its front hose coupled into the train pipe, for the reasons given in Art. **18.**

RUNNING TEST.

21. A running test of the brakes should be made on all trains when leaving the terminal station, to make sure that the brakes set and release properly throughout the train. A running test should also be made when, for any reason, a train is parted during the run.

The engine throttle valve is kept open while this test is being made, the engineer simply making a light service reduction to see whether, and how well, the brakes take hold. As soon as he feels them take hold properly, he releases. While making the reduction, the engineer should note the length of time the train pipe exhausts, since by so doing he can judge the length of the train pipe that is cut into service.

TEMPERATURE TEST.

22. It is well known that the holding power of the brakes varies greatly on different cars, due to defects in the brake system. It is well known, also, that if a brake is applied to a revolving wheel for any length of time, the wheel will become heated; and the longer the brake is held on, or the greater the retarding force exerted by it, the greater will be the resulting temperature of the wheel. Of course, the brakes on a train are

all applied at the same time, so that if they held equally well, the wheels would be of a uniform temperature throughout the train, and no benefit could result from a test of the wheel temperature. It is found, however, that the wheels heat unequally, some being much hotter and others much cooler than the average. If, now, the brakes on the wheels of average temperature are assumed to be doing their proper share of work, those on the wheels of higher temperature must, for some reason, be doing more than their share, while those on the wheels of lower temperature must be doing less than their share; hence, a test and record of the temperature of the wheels of a train, after the brakes have been applied for some time—as in descending a long grade—will give some very interesting and useful information as to the condition and relative holding power of the brakes on different cars. The record should be such that it will show clearly which brakes require attention, and, therefore, should contain a statement of the number of each car on which the temperature of the wheels is very much above or below the average, and whether the wheels are too hot or too cold.

23. Locating Defects.—Having then a record of the defective brakes, stating the comparative temperatures of the wheels, it remains to locate and remedy the defect that causes the trouble.

If the wheels on a certain car are too hot, it indicates either that the brake on that car holds better than the other brakes or else it did not release with the others, and consequently had been dragging. Hence, the piston travel on that car should be measured to see whether it is too short, and the hand-brake inspected to see whether it is fully released. Also inspect the pressure retainer to see whether it is working properly, and the brake cylinder to see whether the piston is stuck out, due to a defect in the cylinder or brake rigging.

If the wheels are too cold, it indicates either that the brake, for some reason, did not hold as well as the others, or did not apply with the others, or else that it released soon after it was set. The brake-piston travel, therefore, should be measured to see whether it is too long—in which case the force exerted by

the brake would be considerably less than with the proper piston travel; or whether it is too short—in which case it is possible that the brake piston does not cover the leakage groove, the brake leaking off, as a result. Also, the brake may not have applied at all, as the cut-out cock may not have been opened; or else it may have released again, due to leakage in the brake cylinder, auxiliary reservoir, triple valve, or—when the brakes have been released and the retainer is supposed to be holding 15 pounds in the brake cylinder—in the pipe leading to the retaining valve.

On roads where there are long down grades on which the retainers must be used, the wheel-temperature test is especially essential. When the brakes are held on for a considerable length of time, some of the wheels are liable to become very hot, and since the heating takes place at the rim, the wheel is subjected to stresses that are liable to cause it to break.

HANDLING TRAINS.

SERVICE STOPS.

24. Train-Pipe Reductions.—In making a service application of the brakes, the amount of the first reduction will depend somewhat on the length of the train. Whatever the length of the train pipe, the first reduction must be sufficient to cause the brake-cylinder pistons to move out far enough to cover the leakage grooves; otherwise the brake will not set, and the air that should have been used in setting it will pass out through the leakage groove and be wasted. If too heavy a reduction is made, the slack of the train, if a freight, will run in so quickly that a severe shock will result.

The amount of reduction necessary to cover the leakage grooves can readily be determined when testing the train or when making the first stops. In passenger service, from 5 to 7 pounds is generally sufficient for the first reduction. With a freight train consisting of, or controlled by, ten air cars, a reduction of from 5 to 7 pounds will give good results. When

the train contains more than this number of air cars, the reduction must be increased accordingly. For example, a train containing twenty-five air cars will probably require an 8-pound initial reduction, while a train of fifty or sixty air cars will probably require a 10-pound reduction.

Preliminary Reduction.—There are several reasons why a heavier preliminary reduction is necessary with a long train than with a short one. The volume of air in the train pipe increases directly with its length, so that the longer it is, the more time is required to make a given reduction in the train-pipe pressure. Now, since train-pipe pressure reduces more slowly on a long train than on a short one, there is a greater chance for the auxiliary air to feed back into the train pipe through the feed groove before it is closed by the triple piston. This reduces auxiliary pressure and has the same effect as though the preliminary reduction had been slighter. Then, again, the slower the train-pipe pressure is reduced, the slower will the auxiliary pressure feed into the brake cylinder, and, consequently, the more air will leak out of the leakage groove and past the packing leather.

Subsequent Reductions.—The amount of the subsequent reductions (following the preliminary reduction) depends somewhat on the length of the train pipe and the condition of the brake apparatus. With the apparatus in good condition the reductions should not, as a rule, be more than from 2 to 6 pounds, being small when the train pipe is short, and increasing as the length of the train pipe increases.

Experiment has shown that a brake grips the wheels better, and, consequently, retards the train more, at slow than at fast speeds for the same train-pipe reduction; therefore, the danger of producing shocks is greatest at slow speeds, and the reductions should be made accordingly. Also, sufficient time must elapse between reductions to allow all of the brakes to set and the slack to equalize throughout the train. If the reductions are made too close together, the effect will be the same as though one heavy reduction had been made. For example, if one 3-pound reduction is followed by another before the train-pipe exhaust ceases, the brakes will set as though a 6-pound

reduction had been made. It must be remembered that the graduating valve in the triple valve does not close until the train-pipe exhaust ceases, and any reduction made before it closes will prevent that event taking place until auxiliary pressure is reduced an amount equal to the sum of the reductions.

Number of Reductions.—The number of reductions to be made in a service application depends on circumstances. It is not good practice to wait so long before applying the brakes that a sufficient number of heavy reductions must be made to cause a full application, in order to make the stop at the proper spot. It is better to make the first reduction at such a distance from the stopping point that a full application of the brakes will not be necessary. The reductions should be moderate and sufficient in number to make not more than a 15-pound train-pipe reduction in bringing the train to a standstill. The engineer then has a reserve braking force at his command that will be of the greatest value in case of emergency while running into a station.

25. Passenger-Train Stops.—An ordinary station stop with a passenger train is generally made with one application of the brakes, and in no case should more than two applications be necessary. A 5- or 6-pound reduction should be made at the proper distance from the stopping point, and this should be followed by a sufficient number of 2- or 3-pound reductions, to bring the train to rest gradually at the proper point. The brakes should be released just before the train stops, so that the car trucks can right themselves while it is still in motion. If this precaution is not taken, there will be an unpleasant lurch backward just as the train stops.

Stops on Grades.—In making a stop on a grade where the brakes must be held on, it is best to use two applications of the brakes. The first application should be made as though the train were to be stopped a little short of the actual stopping point; then release the brakes (without recharging any) when two to four car lengths from the stopping point, depending on conditions. As soon as the car trucks right themselves, apply the brakes again, lightly, and leave them on. A light application,

such as would be made in a case of this kind, does not tilt the trucks much; consequently, no surge is felt as the train stops. On some roads, all service stops with passenger trains are made with two applications of the brakes, and such a practice gives good results, especially on a slippery track, where the wheels are liable to skid at the moment of the final stop.

Overcharging Train Pipe.—In releasing after first application preparatory to making the second, when stopping a train, the brake valve should be thrown to full release and then immediately moved to lap position, as otherwise the train pipe will be overcharged. The aim should be to just raise the train-pipe pressure sufficiently to release the brakes without trying to recharge the auxiliaries any. The feed groove in the triples is small, and if the brake valve is left in release position so long that the train pipe is charged 15 or 20 pounds higher than the auxiliaries, these latter may not have time to equalize with the train pipe before the second application has to be made. Suppose that the train-pipe pressure is 6 or 7 pounds higher than the auxiliary pressure when the second application is about to be made: to set the brakes with the first reduction, the engineer must make a 12- or 13-pound reduction—6 or 7 pounds to make the train pipe equal to the auxiliary pressure, and a further reduction of 6 pounds to apply the brakes. If the engineer makes the ordinary reduction, the brake will not apply, and the train will either run past the stopping point or else the engineer will have to make an emergency application, which will, when the train is running slowly, cause a very disagreeable lurch. The easiest way to avoid this is to not overcharge the train pipe when releasing the brakes for a second and lighter application.

Number of Applications.—It is not good practice to make more than two applications of the brake in stopping a train. Every time the brakes are applied and released, the amount of air taken into the brake cylinder from the auxiliary is discharged into the atmosphere. This reduces the auxiliary pressure, so that on the second application it equalizes with the brake cylinder at a much lower pressure than on the first, while on the third application it equalizes at a very greatly reduced

pressure. For example, if a brake is adjusted so that it will equalize with the auxiliary at about 50 pounds on the first application, it will equalize at about 30 pounds on the second, 20 pounds on the third, and at only about 10 or 12 pounds on the fourth application. It will thus be seen that the power of the brake falls away very rapidly with each application, hence the advisability of making but two applications at the most.

As already stated, two applications are advisable when making a stop on a grade. It will be found advisable, also, to make two applications whenever a close, accurate stop is to be made, such as at water tanks or coal chutes. In each instance, the stop should be made according to the instructions just given for a stop on a grade, and the brakes should be held on until the water or coal has been taken.

Service Stops by Means of Tail Hose.—When the train is to be backed some distance and stopped by one of the train hands by means of the tail hose, the engineer should carry his brake valve in running position until he is given a signal or feels the first application, when he should immediately place the brake valve on lap and leave it there until signaled to release. During the run backwards, the brake valve must, of course, be carried in running position to supply any train-pipe leaks, but it should be lapped in time so that the man making the stop will not be hampered and will have complete control of the train, since he is the man that is responsible for the way the stop is made.

26. Part-Air Freight Trains.—The amount of free slack in a part-air train is principally what makes such a train so difficult to handle without producing shocks, and every time the speed of the train is altered this slack must be taken care of. As already remarked, this free slack must either be gathered in or run out every time the speed of the train is changed, and the more quickly this is accomplished, the greater will be the resulting shock. Also, as remarked in Art. **3**, the extent of the shock will depend on the number and position of the loads in the non-air section, and on the extent to which the air section

resists the blow as the slack is bunched or run out. If there is a sufficient number of air cars to hold well and the loads are at the rear end of the train, the shock will be severe if the slack is bunched quickly; consequently, a train should always be bunched or stretched gradually.

In making a service stop with a part-air train, close the throttle at a sufficient distance from the stopping point, and let the train drift for a short distance, or until it has bunched fairly well. A reduction just sufficient to close the leakage grooves should then be made, and ample time allowed for any slack to run in before a second reduction is made. The second and succeeding reductions should be sufficiently light and numerous to bring the train smoothly and gradually to rest at the proper point, care being taken that one reduction is not made until after the exhaust of the previous one has ceased.

As a rule, the brakes should be held on until the train has come to rest, as otherwise a shock tending to tear the train in two will be caused, due to the slack running out. They should be released immediately after stopping, however, so that the brakes on the air cars may not be rigidly set when the non-air cars run back—as they will do when the spring slack eases up.

Use of Hand-Brakes.—It should not be necessary to use hand-brakes to assist the air brakes in making a service stop, but in case this has to be done, the brakes immediately back of the air cars should be used, and not those at the rear end of the train. In case of danger, when the stop must be made quickly, all hand-brakes should be set. When hand-brakes are used, they should be released before the air brakes, as otherwise a break-in-two is liable to occur. In backing a part air-train out of a siding, however, a few hand-brakes should be applied at the rear end of the train before the air brakes are applied, so that the slack of the non-air section will not run out violently when the air brakes are applied to stop the train.

Water-Tank and Coal-Chute Stops.—It is a very difficult matter to apply or release the brakes of either a part-air or an all-air freight train at slow speeds, without a more or less severe shock resulting; hence, the safest way to make a close, accurate stop with a freight train, is to stop short of the tank or chute,

cut the engine off, take coal or water, and then couple up to the train again.

A good way to make an accurate stop with a "lone" engine is to apply the brakes in such a way that it will tend to stop 3 or 4 feet short; then use a little steam just before it ceases to move, and the instant the throttle is closed the engine will stop.

27. All-Air Freight Trains.—Although in making stops with an all-air train the engineer does not have to deal with a lot of free slack, as in the case of a part-air train, yet if the train is very long he will have trouble with slack, since the head-end brakes apply and release sooner than the rear ones, in consequence of which the slack plays in or out when the first reduction is made or the brakes are released. Also, as stated in Arts. 4 and 5, uneven distribution of load and unequal travel of the brake pistons complicate matters so that good judgment and skill must be exercised in handling such a train or else rough treatment of freight is sure to follow.

Both the first and succeeding reductions must be heavier (according to the length of the train) than for short freight or for passenger trains (see Arts. 24 and 25). The first should be sufficient to cover all the leakage grooves, and no succeeding reduction should be made before the train-pipe exhaust, due to the previous one, has ceased. After one or two applications of the brake, the engineer can judge pretty closely what reductions to make in order to handle the train smoothly.

In making a service stop with a long all-air freight train, the first reduction should be made at a sufficient distance from the stopping point, and once the brakes are applied they should be held on until the train has come to a standstill. It is almost impossible to release the brakes on a very long train at slow speed without breaking the train in two, unless the retainers are used on the engine. Some roads are equipping their engines with retainers or other appliances that are intended to prevent the slack from running out violently in case it is necessary to release at slow speeds.

If necessary to release brakes while the train is moving, sufficient excess pressure should be pumped up to insure the

prompt release of the brakes, and the engine retainers, if the engine is supplied with them, should be cut into service. Care should always be taken not to work steam until all brakes on the train have released, and even then the throttle should be opened cautiously, for if steam is worked before the rear-end brakes have released, the train is pretty certain to be torn in two. One second for each car in the train should be allowed after releasing the brakes before steam is used, so that sufficient time will be allowed for all brakes to release and the drawbar springs to adjust themselves.

EMERGENCY STOPS.

28. Brake Stops.—In cases of actual emergency, the brake valve should be thrown to full emergency position *and left there*, and sand should be used. Of course it is possible to get the emergency action of the brakes without losing all the train-pipe air, but it is not good policy to try to do so in times of pressing danger. In the first place, if several cars with plain triples, or with brakes cut out happen to be placed together, only the brakes ahead of such cars will go into quick action, while the ones back of them will set with a partial-service application only. If the valve is left in emergency position, a full application will be had on the cars back of, and full emergency on those ahead of, the cars with plain triples. Another possibility is that during the excitement the engineer may, in trying to bring the valve back to lap, move it to running position, thus releasing the brakes; or if the valve is moved to lap too quickly, the surge of the air in the train pipe may kick off the forward brakes.

Everything considered, the safest plan is to move the brake valve to emergency position and leave it there, and not try to save air in the hope that if the train can be stopped in time the brakes can be released and the train backed up and thus avoid the danger. No matter what the position of the brake valve or the kind of train—whether all-air or part-air—in case of emergency, the brake valve should be moved to emergency position. It makes no difference whether the brakes have been

applied in a partial- or even a full-service application—the handle should be moved to emergency just the same. In the former case, a full emergency application may not be obtained, but a partial emergency may; and certainly a full-service application would be. In the latter case, if all the brakes were set full, no advantage would be gained, but if any of the brakes had not equalized with their auxiliary, or if some of the brakes had partially or wholly leaked off, the reduction would cause them to equalize with their auxiliaries, thus making them hold better.

29. Reversing the Engine.—No matter how poor the driver and tender brakes are, if they are applied, the engine should never be reversed with the expectation of making a shorter stop than could be made with the brakes alone; reversing the engine under such conditions may cause the brakes to lock and slide the drivers, in which case the retarding power of the engine is practically lost.

30. Accidental Emergency Stops.—Under this head are supposed to be included all emergency stops other than those purposely made by the engineer. Whenever the brakes apply suddenly without his aid, he should immediately lap the brake valve and leave it in that position, so as to bring the train to a standstill as soon as possible and save main-reservoir pressure for releasing brakes when the proper time comes for so doing. A sudden, unexpected application of the brakes may be caused by a conductor's valve being opened, by a burst hose, or by the train parting.

RUNNING.

POSITION OF BRAKE VALVE.

31. The brake valve should always be carried in running position while the brakes are off, since this is the only position in which excess pressure can be carried, and train-pipe leaks be supplied by air from the main reservoir. In speaking of excess pressure, it is meant that there is an excess of pressure in the main reservoir over that in the train pipe; that is, when

main-reservoir pressure exceeds train-pipe pressure by a certain amount, *that* amount is called the excess pressure. The excess pressure, therefore, is carried in the main reservoir, and it is very important that it be carried and maintained at all times while the train is running. A sufficient excess should be carried, so that when it is turned into the train pipe to release the brakes, it will do so promptly and also recharge the auxiliaries promptly.

The brake valve should not habitually be carried in release position; in fact, ordinarily, it should not be carried there at all. It should simply be moved to, and left in, that position until brakes have been released, when it should at once be moved to running position.

SETTING OUT A CAR.

32. In setting out a car at a way station, first of all, release the brakes; then close the angle cock on each side of the hose that is to be parted; then part the hose by hand, and hang up properly in the dummy couplings the hose of the car that is to be set out. Before the car is left on the side track, the air brake should first be released and the release valve on the car held open until all the air has been exhausted from the auxiliary reservoir; then the hand-brake should be applied (if necessary) to hold the car. The air brake should never be depended on to hold one or more cars on a grade for any length of time when not connected to the engine, since the brakes may leak off and allow the cars to escape down the grade uncontrolled. In case cars must be left standing on a grade, always release the air brakes and apply the hand-brakes.

PICKING UP CARS.

33. When the engine is backed up to a number of cars that are to be switched or picked up, the train pipe on which cars may be empty, it is well to apply and release the engine brakes a couple of times without recharging the auxiliary, and then place the brake valve on lap before the tender angle cock is

opened. The auxiliary pressure will then be so low that if the engine brake *does* set in full when the angle cock is opened, the auxiliary and brake cylinders will equalize at such a low pressure that the main-reservoir pressure can very readily release them, and thus time will be saved, as the cars can be charged while they are being moved.

In coupling up a car or cars that have been picked up, and which may not be fully charged, the following precautions should be observed: After coupling the hose, first open the angle cock on the car that was picked up, and then the one on the charged section of the train, opening the latter cock slowly so that pressure will not be fed into the undercharged car faster than it is supplied to the train pipe from the main reservoir. By taking this precaution, both time and air will be saved.

HOSE BURSTING.

34. As already mentioned, in the event of a hose bursting the engineer should immediately lap the brake valve, and, as soon as the train stops, send out flags. The hose should be replaced by a new one (if at hand) or by the rear hose on the last car of the train, and the brakes then tested to see whether they operate properly. If unsafe to replace the hose and test the train at the time, the angle cock immediately in front of the burst hose should be closed; the brakes back of it should then be bled off, and the train moved to a safe place, where the hose can be replaced and the brakes tested.

To Locate a Burst.—If the leak is not too large, the brake valve should be left in partial-running position; the leak can then be located by the sound made by the escaping air, while at the same time main-reservoir pressure can be maintained. With a large leak, however, it would be impossible to open the valve wide enough to make a sound and still maintain the main-reservoir pressure; consequently, the brake valve should be moved periodically from lap to full release and back again. This will produce an intermittent sound by means of which the leak can be located.

BLEEDING BRAKES OFF.

35. There are two methods by which a triple valve can be made to release a brake. One is to increase the train-pipe pressure above that in the auxiliary—the other to reduce the auxiliary pressure below that in the train pipe. The first is the usual way—the second method is the one employed to bleed off a brake. To do this, the **release valve,** or **bleed cock,** as it is often called, should be held open until air escapes from the triple exhaust, when it should immediately be closed. The blow at the exhaust indicates that the triple has moved to release position, and any further reduction of auxiliary pressure is not only a loss of air, but also causes a reduction in the train-pipe pressure, which in some cases may cause other brakes to apply.

BREAKING-IN-TWO OF TRAIN.

36. In case an all-air train should break in two, the brake valve should be lapped at once and the engine throttle closed, so as to bring the front section to a standstill as soon as possible. With such a train, the engineer should not attempt to keep the head end out of the way of the rear end, for the reason that they are pretty sure to come together in any event; and the less the two sections separate, the less damage will be done when they come together. Flags should be whistled out, and as soon as the sections come to a standstill, the angle cocks each side of the break-in-two should be closed, and the brakes on the front section released. As soon as the signal is given, the front section should be backed up and coupled to the rear section, and the brakes on the whole train released. A test should then be made to see whether the brakes are working properly.

In the event of a part-air train breaking in two, the course to pursue will depend on whether the break occurs in the air section, or back of it. If it occurs in the air section, pursue the same course as with an all-air train; if it occurs in the non-air section, the brakes, of course, will not set on the air section, and the engineer should endeavor to keep the head section out of the way of the rear section, until the latter can be brought to a standstill.

HANDLING TRAINS ON LONG DOWN GRADES.

37. The manner in which the braking should be done on a long down grade depends to a considerable extent on local conditions, which may differ widely on different hills; consequently, no rule can be given that will cover all conditions. In order to give instructions for braking on any particular hill, the location of the easy and heavy parts of the grade should be definitely known; hence, instructions are usually issued by the companies, covering the conditions in each case.

In the absence of specific instructions, however, the following will serve as a guide: The pump should be run faster than usual while on the grade, so as to recharge the main reservoir promptly when necessary. Turn the retainer handles up just before the descent is begun, and make a moderately heavy reduction while the speed of the train is slow. It will be remembered that a given reduction will cause the brakes to hold better at slow, than at high, speed; hence, much better control of the train can be maintained, and air saved, by making the first reduction before the train has gained much headway. Good judgment should be used in making the succeeding reductions, and they should be sufficient in number and amount to maintain the speed of the train well within safe limits. With the use of pressure retainers and frequent light reductions and releases, the auxiliary pressure can be held up to the proper amount.

When possible, curves and easy parts of the grades should be selected on which to release the brakes and recharge the auxiliaries; also, the last reduction before releasing should be heavier than the others, so as to slow down the speed considerably before releasing, since it not only will take a little longer for the brake-cylinder pressure to reduce down to 15 pounds, but the pressure in the brake cylinder will have a greater retarding effect at the slower speed. The auxiliaries should be fully charged just before the steep parts of the grade are reached, so as to have sufficient braking power to hold the speed within bounds while descending. Safety should, of

course, be the first consideration, and, in general, the best results will be obtained by a slow speed and the use of retainers while on the grade.

QUICK ACTION DURING SERVICE REDUCTION.

38. If, when making a service reduction, the brakes set quick action, the trouble is probably due to the gummy, dirty condition of some one or more of the quick-action triples. After the first application, however, no trouble is likely to be experienced, as the pistons have torn loose the gum and dirt that caused them to stick.

LOCATING DEFECTIVE TRIPLE.

39. Quick action following a service reduction is due to one of the triples not operating until the train-pipe pressure is reduced considerably below the auxiliary pressure, and then when it does operate, it moves so quickly as to put the quick-action valves into operation, thus causing the other triples to follow in quick action.

To locate the defective triple, make a service reduction in train-pipe pressure of 5 or 6 pounds, then look the train over to find the brake piston that has not moved out of the brake cylinder. When this brake is found, it may be cut out at once, or if time will permit, it may be tried again to see if it will cause quick action. Usually, a gummy triple does not cause quick action but once.

Sometimes a triple that is causing quick action, when service applications are being made, may be located by watching the ground under the cars. The vented train-pipe air striking the ground will cause a little dust to rise.

BRAKES STUCK ON.

40. If it is found that the brakes cannot be released by placing the brake valve in full-release position, it should be placed on lap to obtain excess pressure, and then thrown into full release. The brakes on a long train are likely to stick after

an emergency application, especially if the train pipe has been emptied of all pressure, or if the main-reservoir capacity on the engine is small.

USE OF SAND.

41. It is well known that by the proper use of sand the wheels may be made to "grip" the rails much better, thus lessening the danger of the wheels being flattened from sliding. On the other hand, if the sand is not properly used and the wheels begin to slide, the flat spots formed will be worse than if no sand were used.

When necessary to use sand in making a stop, the rails under the entire train should be sanded by the time the first application is made, or at least before the brakes have applied very hard, and the sand should be used continuously until the train comes to a standstill. Sand should never be used after the wheels have begun to slide, since it will not start them turning again, but will simply increase the wear on the wheel and thus make the resulting flat spot bigger than it otherwise would be. In the event of the wheels sliding, the brakes should be released, if practicable, and the rails sanded; after which the brakes may be applied again, but the rails should be continuously sanded until the stop is made. Whenever the rail is bad, sand should be used when applying the brake, to avoid skidding the wheels.

It is bad practice to attempt making a stop without using sand and then after the brakes have been fully applied and it looks as though the train would not stop soon enough, to drop sand on the rails. Some of the wheels may be sliding, and the sand will be the cause of some very bad spots.

WHEELS SLIDING.

42. When the brakes are applied there are two forces acting on the moving wheels: one, the force exerted by the brake, which tends to prevent the wheel from turning, and thus tends to cause it to slide over the rail like a sled runner; the other, the force exerted between the wheel and the rail, which resists

this tendency to slide, and thus tends to keep the wheel turning. As long as the latter force is greater than the former, the wheel will continue to revolve; but if, for any reason, the force exerted by the brake is the greater, the wheel will slide. It will thus be seen that a wheel may be made to slide either by reducing the adhesion between the wheel and the rail (as when the rails are slippery) or by increasing the force exerted by the brake above a certain amount.

Apart from the matter of slippery rails, therefore, the wheels may be slid: if the piston travel is too short, whether due to its adjustment, to the hand-brake being partially set, or otherwise; if the leverage is too great; if the brake fails to release after making a stop; if a heavy reduction is made when the train is moving slowly; or if the auxiliaries are overcharged and allowed to equalize with the brake cylinders. Some types of driver brakes may lock and skid the wheels if the piston travel is allowed to become too long.

USE OF CONDUCTOR'S VALVE.

43. Each car in passenger service, and some cabooses in freight service, are provided with a valve called the **conductor's valve** (see Fig. 1, Part 1), by means of which the brakes can be applied from the train. This valve is connected to the train pipe by means of a branch pipe, and when the valve is open it makes a direct passage from the train pipe to the atmosphere. The conductor's valve is intended to be used only in cases of emergency, when it is necessary to stop the train as soon as possible. It should be opened fully and held open until the train comes to a stop, for if it should be closed while the engineer's brake valve is in running position, the brakes will be released again.

DOUBLE-HEADING.

44. In **double-heading,** it is the duty of the leading engineer to handle the brakes, and the cut-out cock in the train pipe under the brake valve of the following engine should be turned to the "cut-out" position, so as to give

him absolute control. After cutting out the brake valve on the following engine, the following engineer should place the handle of his brake valve in running position and keep the air pump working so as to maintain 90 pounds pressure in the main reservoir, to use in case the leading engineer desires assistance in releasing the brakes. In that event the following engineer should turn the cut-out cock to its normal position, and return it to "cut-out" position as soon as the brakes release.

If the following engine is not supplied with a cut-out cock, the brake valve should be carried on lap instead of in running position.

PISTON TRAVEL AND ITS ADJUSTMENT.

LONG AND SHORT TRAVEL.

45. The subject of **piston travel** and **piston-travel adjustment** is an important one, and should be thoroughly understood, since not only the efficiency of the brake, but also the smoothness with which a train can be handled, depends to a great extent on the proper adjustment of the brake-piston travel.

The auxiliary reservoir used with any brake cylinder is of such a size that if charged to 70 pounds it will equalize with the brake cylinder at 50 pounds, if the travel of the brake piston is adjusted to 8 inches. If the piston travel is less than 8 inches, the auxiliary and brake cylinder will equalize at a higher pressure than 50 pounds, while if the travel is more than 8 inches, they will equalize at a lower pressure. When a train-pipe reduction is made, air passes from the auxiliary (into the brake cylinder) until the pressures in auxiliary and train pipe are about equal. Thus, for a given train-pipe reduction, the same amount of air is discharged into the brake cylinder, regardless of the length of the piston travel. That is to say, if a 7-pound reduction were made, the same amount of air would pass into a brake cylinder having a 5-inch piston travel as would pass if the travel were 8 inches. With the 5-inch travel,

however, the air would have to fill less space than with the 8-inch travel; hence, it can readily be seen that the brake with the short travel will develop the greater pressure.

EQUALIZATION TESTS.

46. The following table gives the results of a number of tests made with a freight equipment, each pressure given being the average of several trials with each piston travel. It shows the pressure obtained in the brake cylinder for different piston travels.

BRAKE-CYLINDER PRESSURES.

Service Reduction From 70 Pounds Train Pipe.	Piston Travel.							
	4″	5″	6″	7″	8″	9″	10″	11″
7	25	23	17½	13	10½	8		
10	49	43	34	29	23½	19½	17	14
13	57	56	44	37½	33	29	24	20
16	57	56	54	47½	41½	35	29	24
19	57	56	54	51	47	40	36½	32
22	57	56	54	51	50	47½	44	39
25	57	56	54	51	50	47½	47	45

Explanation of Table.—The first column on the left gives the reduction in train-pipe pressure; the second column gives the brake-cylinder pressure resulting from the corresponding reduction in column 1, when the brake-piston travel is only 4 inches; the third column gives the resulting brake-cylinder pressure when the piston travel is 5 inches, and so on for the other columns. For example, a train-pipe reduction of 7 pounds will result in a brake-cylinder pressure of 25 pounds with a 4-inch travel, or 8 pounds with a 9-inch travel; a 10-pound reduction will result in 43 pounds brake-cylinder pressure with a 5-inch travel, and only 14 pounds with an 11-inch travel.

By studying the table carefully, some very useful information can be derived. It will be seen that the short-travel

brakes equalize the soonest, and with less train-pipe reduction, and exert a greater pressure than the long-travel brakes. For instance, a 13-pound reduction will cause all brakes with 4-inch travel to equalize at 57 pounds pressure, and with 5-inch ones to equalize at 56 pounds; while a 25-pound reduction is necessary to set a brake full with a 10- or 11-inch travel, and then they equalize at only 47 pounds and 45 pounds, respectively.

It will be seen, also, that if three brakes, with, say, 4-, 8-, and 11-inch travel, respectively, were in the same train, the retarding force exerted by each would vary greatly at each reduction. For instance, a 7-pound reduction would cause the first to develop 25 pounds pressure per square inch; the second, 10½ pounds; while the pressure in the cylinder having the 11-inch travel would not be sufficient to move the piston out the full stroke. Now, if the brake cylinders were of 10-inch diameter, a pressure of 25 pounds per square inch in the short-travel brake would develop a total force of 1,963 pounds; 10½ pounds per square inch in the medium-travel brake would develop a total force of 825 pounds; while the long-travel brake would hardly develop sufficient power to force the piston to its full stroke. Thus, of these three brakes, with a 7-pound reduction, the holding power of the first would be nearly 2½ times as great as that of the second, while the third would be altogether ineffective. It is this difference in holding power, due to unequal piston travel, that makes it so difficult to handle freight trains smoothly.

To sum up briefly, the table shows: (1) that the short-travel brakes in a train hold harder at each reduction than the long-travel ones; (2) that they equalize with their brake cylinders with a less train-pipe reduction, hence equalizing sooner than the long-travel brakes; (3) that they equalize at a higher pressure; (4) that since they equalize at higher pressure, they must release later than the brakes with long travel, after a full reduction.

When the train-pipe pressure is increased to release the brakes, it will release those having a 10-inch travel at 47 pounds pressure, but it must be increased 9 pounds more, or

to 56 pounds, to release those having a 5-inch travel. As soon as the first brakes release, their auxiliaries commence recharging, thus making train-pipe pressure increase more slowly than it otherwise would, and delaying the release of the short-travel brakes. If sufficient excess pressure to release the short-travel brakes is not carried, the wheels will probably be slid while the brakes are being pumped off, and bad spots will result. Besides this, the train is subjected to severe wrenches tending to break it in two, on account of the long-travel brakes releasing before the others. However, if the travel is adjusted within certain limits, all brakes will start releasing at about the same time, the tendency being for the long-travel brakes to release first. If the travel were uniform throughout the train, the tendency would be for the brakes nearest the engine to release first, since train-pipe pressure is increased there first. All brakes should begin releasing at about the same instant (regardless of the difference in piston travel), if none of them have been set in full; this is due to the fact that until a brake equalizes, its auxiliary pressure is practically equal to train-pipe pressure.

RUNNING TRAVEL.

47. The piston travel is greater by from 1 to 2 inches when the train is running than when standing still, on account of (1) loose journal brasses, allowing the wheels to move; (2) loose boxes in pedestals; (3) loose truck kingbolts, allowing the trucks to pull together; and (4) the spring in brake beams, levers, or connections. The amount that the brake piston travels when the brakes are applied and the train is in motion is called the **running travel.** Brake beams are sometimes so hung that the brake shoes pull down lower on the wheels when the brakes are applied, and since in that case the shoes travel farther to touch the wheels, the piston travel is increased.

Also, the travel is generally greater when the car is loaded than when unloaded. If the brake beams are hung to the side sills of a car or to the bolster, they will be lowered

(consequently increasing the travel) when the car is *loaded*, and raised again (shortening the travel) when it is *unloaded*.

To avoid this bad effect, some roads hang the brake beams to such a part of the truck that the center of the brake shoes is always the same distance from the rails, regardless of whether the car is loaded or not. This method gives very good results.

PROPER PISTON TRAVEL.

48. The different parts of the air-brake apparatus are so designed and constructed that the proper brake-shoe pressure will be obtained—in a full application of the brakes—with a pressure of 50 pounds per square inch in the brake cylinder. The brake, therefore, would be safer and more efficient if the piston travel were always to remain such as to just give 50 pounds pressure in the brake cylinder—between 7 and 8 inches—but as the brake shoes wear quite rapidly, the travel is bound to increase unless (as such wear proceeds) this travel is automatically adjusted, by means of a slack adjuster. Automatic slack adjusters not being in general use, it has been customary on most roads to take up the shoe slack on passenger cars and tenders until the piston travel is about 6 inches; the brake is then allowed to run until the wear of the brake shoes increases the travel to 8 inches, when the slack is again taken up.

The limits between which the piston travel is allowed to vary are, on most roads, as follows: For passenger-car and tender brakes, between 6 and 8 inches; for standard freight cars, between 5 and 9 inches. On the engine, one auxiliary reservoir supplies air for the two driver-brake cylinders; consequently, a 1-inch travel of each of the driver-brake pistons is equivalent to a 2-inch travel of a car-brake piston. On some roads the driver-brake piston travel is allowed to vary between $\frac{1}{3}$ and $\frac{2}{3}$ of the full stroke of the piston. The better practice, however, is to use an air gauge on the brake cylinder and adjust and maintain the travel so that 50 pounds per square inch will be obtained in the brake cylinder on a full application of the brakes.

MEASURING THE PISTON TRAVEL.

49. To measure the brake-piston travel, force the push rod—if one is used—into the sleeve until it bottoms on the brake piston, and the latter is forced against the cylinder head; then make a mark on the end of the cylinder and measure the distance between the mark and the center of the lever pin in the push rod. Apply the brake in full, and again measure from the same mark on the cylinder to the center of the lever pin; the difference in the measurements will be the amount that the piston travels.

If it is desired to measure the piston travel on an uncharged car, proceed as before, only in this case the brake will have to be set by hand; if necessary, use a piece of wood or a bar of iron as a lever to set them up tight. This method can only be used on cars on which the air brakes and hand-brakes move the piston lever in the same direction in applying the brake.

ADJUSTING BRAKES.

50. Car Brakes.—With the Hodge system in regulating the piston travel of a car or tender brake, the slack of the brake shoes is taken up by means of the truck dead lever. This is accomplished by moving this lever so as to reduce the shoe clearance, since the less shoe clearance there is, the less the piston will have to move to draw the shoes up against the wheels. The top of the dead lever is held by a pin that runs through a guide and the lever, the top of the lever traveling between the sides of the guide. The position of the lever in the guide can be changed by removing the pin and moving the lever until it connects with one of the many holes in the guide. Extra holes are sometimes put in other connections of the brake rigging so that, if necessary, part of the slack may be taken up there. For instance, if sufficient slack cannot be taken up at the truck dead lever, one or two holes should be taken up in the other connection and the travel then adjusted by means of the truck dead lever; with the Stevens system of coach brakes, the slack is taken up in the bottom rods reaching from one truck lever to the other.

On most freight cars, both the hand-brake and the air brake move the levers in the same direction in applying brakes; hence they are said to work together. On nearly all passenger, and a few freight, cars, however, the hand-brake and the air brake move the levers in opposite directions; if, then, the hand-brake chain is wound up a little, the piston travel will shorten a corresponding amount when the air brake is next applied. When the hand-brake and the air brake work together, winding up the brake chain does not shorten the piston travel.

The practice of shortening the piston travel by winding the hand-brake up a little, instead of moving the dead lever, is a bad one, and is decidedly dangerous. If the brake dog on the hand-brake should work out of the ratchet, the slack would run out; also the extra strain on the brake chain tends to break it. If too much chain is wound up, the travel may be shortened so much that the piston will not cover the leakage grooves and the brake will not apply. Then, again, if the air brake tends to turn the hand-brake standard in a direction opposite to that which it must be turned by hand to set the brakes, there is always danger of a person being hurt should he try to turn the hand-brake when the engineer happens to be setting the air brakes.

51. Cam Driver-Brakes.—Two views of the push-down type of cam driver-brake are shown in Fig. 1, (*a*) being a side view and (*b*) an end view. As air is admitted into the brake cylinder *C*, the piston and, consequently, the cross-head *h*, is forced downwards, thus causing the cams to roll on each other and move the cam-screw pins outward, pressing the shoes against the wheels.

The distance between the link pin *a* and the cam-screw pin *b* can be changed by means of the cam-screw *c*, and it is by means of this screw that the piston travel is adjusted. To shorten the travel, the distance between the pins is lengthened.

In taking up the slack of the brake shoes, care must be exercised to lengthen both cam-screws the same amount, so that the point of contact of the cams will be in line with the center of the brake cylinder. Sufficient shoe clearance should be allowed.

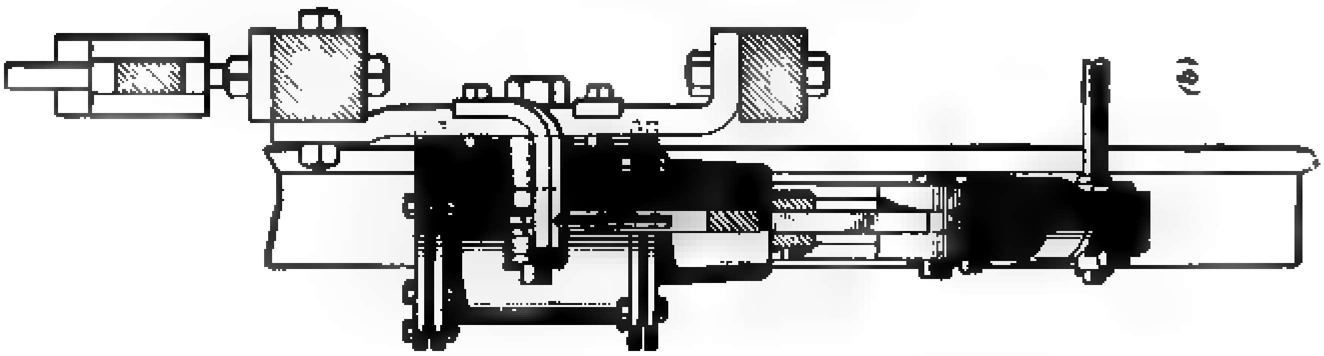


FIG. 1

52. Outside Equalized Driver Brake.—In Fig. 2 are given two views of the outside equalized driver brake as generally used at the present time on engines having three or more pairs of drivers, (*a*) being a side view and (*b*) a plan view. In this type of brake, the piston is connected to the brake rod *R* by a bell-crank lever *L*, which turns on the pin *P*, so that when the brake piston is forced outwards, the brake rod *R* is drawn backwards and applies the brake shoes to the wheels.

A slack adjuster *T* (popularly spoken of as a "turnbuckle") is provided for the purpose of taking up the slack as the brake shoes wear. This is accomplished by loosening the locknut *s* on the screw bolt and turning the bolt in such a way as to pull the brake rod *R* backwards, thus moving the brake shoes up nearer to the wheels. Other kinds of slack adjusters, also, are frequently used. The pipe *p* leads from the brake cylinder to the triple valve.

LEVERS AND LEVERAGE.

53. The foundation brake gear on engines, tenders, and cars consists simply of a system of levers connected together by rods; and it is by means of these levers that the force developed in the brake cylinder is transmitted and applied to the wheels.

It is desirable, therefore, to be able to calculate the braking power that a system of levers is capable of exerting, and to do this the different classes of levers must be studied.

SIMPLE LEVERS.

54. The Straight Lever.—A lever is any bar that is capable of being turned about a fixed axis or pivot, called the **fulcrum,** as in Figs. 3, 4, and 5. In these figures, *W*, the object to be lifted, is called the *weight;* the force *P*, employed to lift the weight, is called the *power;* and the point *F*, round which the lever turns, is called the *fulcrum.* That part of the lever *Fb* between the fulcrum and the weight is called the *weight arm* of

(a)
FIG. 2.

the lever, while the part Fc between the fulcrum and the power is called the *power arm.*

The fulcrum F, it is to be remembered, is stationary, and the lever is perfectly free to turn on it. Now, if the weight W is great enough, it will cause the lever to turn or rotate about the point F against the action of the power P; if, on the other hand, the power is great enough, it will cause the lever to rotate about F against the action of the weight W. In other words, it will raise the weight. When the power P is just sufficient to balance the weight W, and the lever, therefore, does not move, it will be found that:

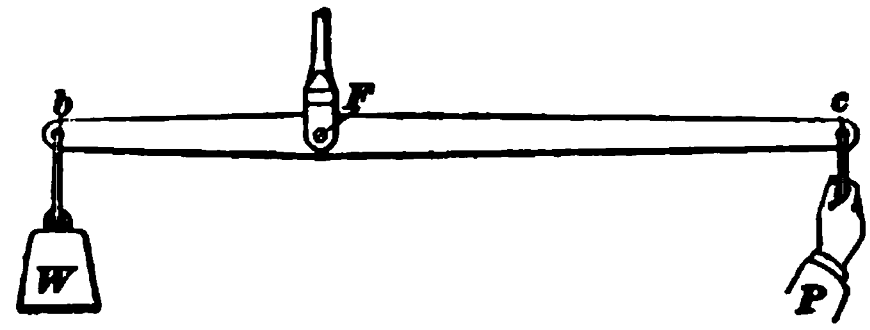


FIG. 3.

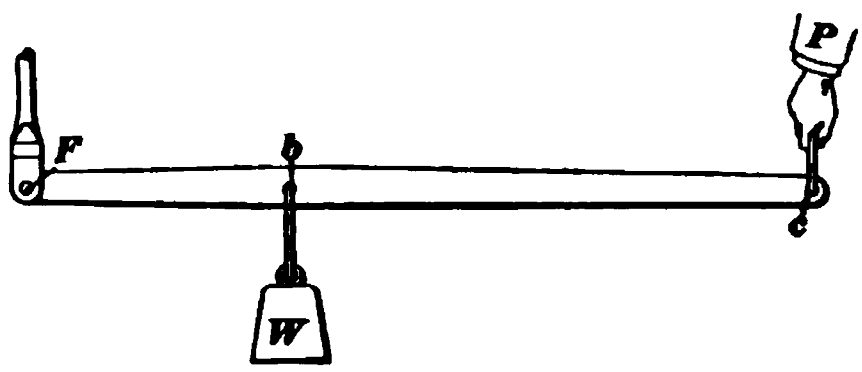


FIG. 4.

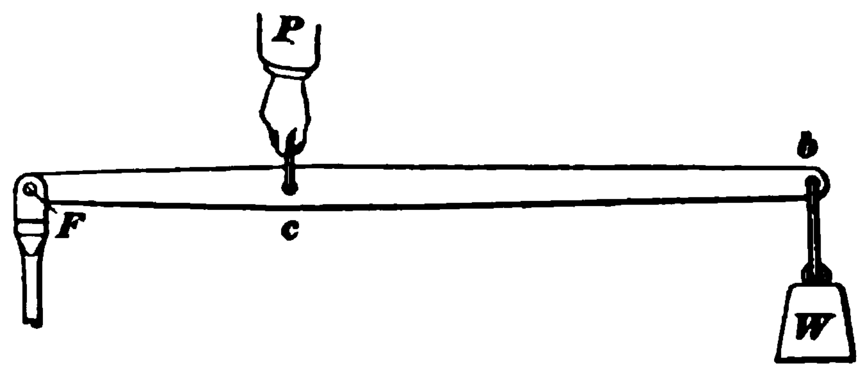


FIG. 5.

Rule I.—*The power multiplied by the power arm is equal to the weight multiplied by the weight arm;* that is, the power P multiplied by the distance Fc will just equal the weight W multiplied by the distance Fb.

Or, expressing this in symbolic form,

$$P \times Fc = W \times Fb.$$

From this it can readily be shown that

$$P = \frac{W \times Fb}{Fc}; \qquad (1)$$

$$W = \frac{P \times Fc}{Fb}; \qquad (2)$$

$$Fc = \frac{W \times Fb}{P}; \qquad (3)$$

$$Fb = \frac{P \times Fc}{W}; \qquad (4)$$

where P = force or power applied;
W = weight;
Fc = length of power arm;
Fb = length of weight arm.

It will be seen that only four quantities enter into these equations, as the foregoing expressions are called, and if any three of these quantities are known, the other can be determined by means of one of the equations. The use of the equations, or formulas, is illustrated in the following examples:

EXAMPLE 1.—If the power arm of the lever is 20 inches long and the weight arm 10 inches long, what power must be applied to just balance a weight of 1,000 pounds?

SOLUTION.—In this example we see that $Fc = 20$, $Fb = 10$, $W = 1{,}000$, and P is to be found; therefore, substituting these values in equation (1), we find that

$$P = \frac{W \times Fb}{Fc} = \frac{1{,}000 \times 10}{20} = 500 \text{ pounds. Ans.}$$

EXAMPLE 2.—If a power of 1,000 pounds is applied to the lever of example 1, how many pounds weight will it balance?

SOLUTION.—In this example, Fc again $= 20$, $Fb = 10$, and $P = 1{,}000$; W is to be determined, hence equation (2) will be used. From this,

$$W = \frac{P \times Fc}{Fb} = \frac{1{,}000 \times 20}{10} = 2{,}000 \text{ pounds. Ans.}$$

EXAMPLE 3.—Suppose a force of 1,600 pounds at P has either to support a weight or exert a force of 3,200 pounds at W. How long must the power arm be, the weight arm being 10 inches?

SOLUTION.—In this case, $P = 1{,}600$, $W = 3{,}200$, and $Fb = 10$. Therefore,

$$Fc = \frac{W \times Fb}{P} = \frac{3{,}200 \times 10}{1{,}600} = 20 \text{ inches. Ans.}$$

EXAMPLE 4.—If, in example 3, the power arm were 10 inches long, what length would the weight arm have to be?

SOLUTION.—Here $P = 1{,}600$, $W = 3{,}200$, and $Fc = 10$; hence,

$$Fb = \frac{P \times Fc}{W} = \frac{1{,}600 \times 10}{3{,}200} = 5 \text{ inches. Ans.}$$

55. Suppose that the weight arm Fb of the lever shown in Fig. 6 is twice as long as the power arm Fc; then, if the lever

is turned about the fulcrum F until it occupies any other position, as $b'Fc'$, it will be found by actual measurement that the point b of the lever travels just twice as far in moving to b' as c does in moving to c'. If the weight arm were four times as long as the power arm, it would be found that the point b would always travel four times as far as the point c when the lever was moved through any distance. In other words, the distances through which the power and the weight move are always in the same ratio as the lengths of their arms.

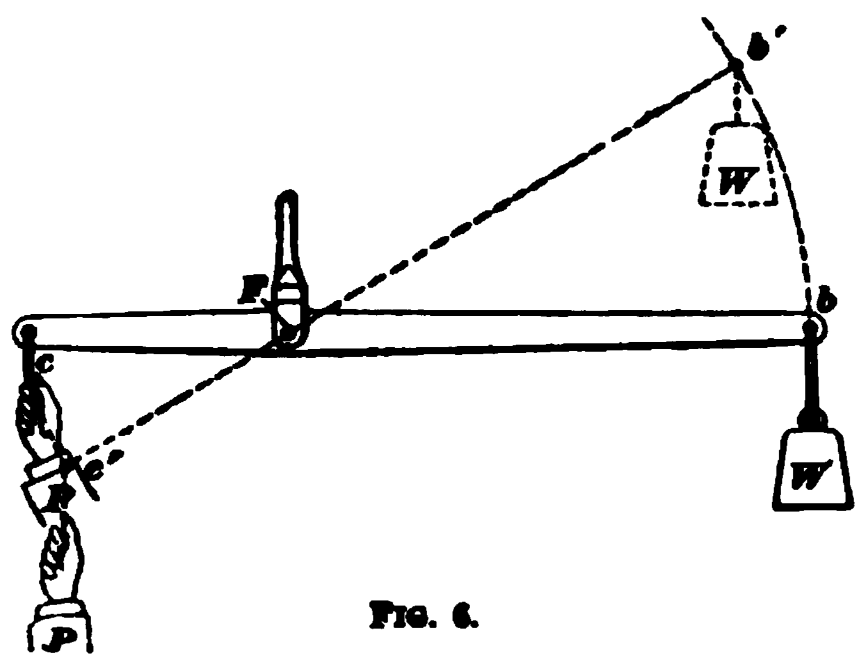


FIG. 6.

This being true, we may, in place of the statement that the power multiplied by the power arm is equal to the weight multiplied by the weight arm (rule I), write:

Rule II.—*The power multiplied by the distance through which the power moves is equal to the weight multiplied by the distance through which the weight moves.*

If the power moves through a distance $c c'$ while the weight moves through a distance $b b'$, then, by substituting $c c'$ and $b b'$ for Fc and Fb, respectively, in the equations (1) and (2) of Art. **54**, we have:

$$P = \frac{W \times b b'}{c c'}, \text{ and } W = \frac{P \times c c'}{b b'}.$$

EXAMPLE 1.—If the point of application b of the weight travels 2 inches while the point of application c of the power travels 8 inches, what force must be exerted on the lever to cause it to exert a force of 2,000 pounds?

SOLUTION.—In this case, $c c' = 8$, $b b' = 2$, and $W = 2{,}000$; hence,

$$P = \frac{W \times b b'}{c c'} = \frac{2{,}000 \times 2}{8} = 500 \text{ pounds. Ans.}$$

EXAMPLE 2.—In the foregoing example, if a force of 1,000 pounds were applied at P, what force would the lever exert at W?

SOLUTION.—Here, again, the weight moves 2 inches while the power moves 8 inches; hence,

$$W = \frac{P \times c c'}{b b'} = \frac{1{,}000 \times 8}{2} = 4{,}000 \text{ pounds. Ans.}$$

The principle embodied in rule II was made use of by Mr. H. A. Wahlert in inventing a method for determining the braking power developed by a cam driver-brake.

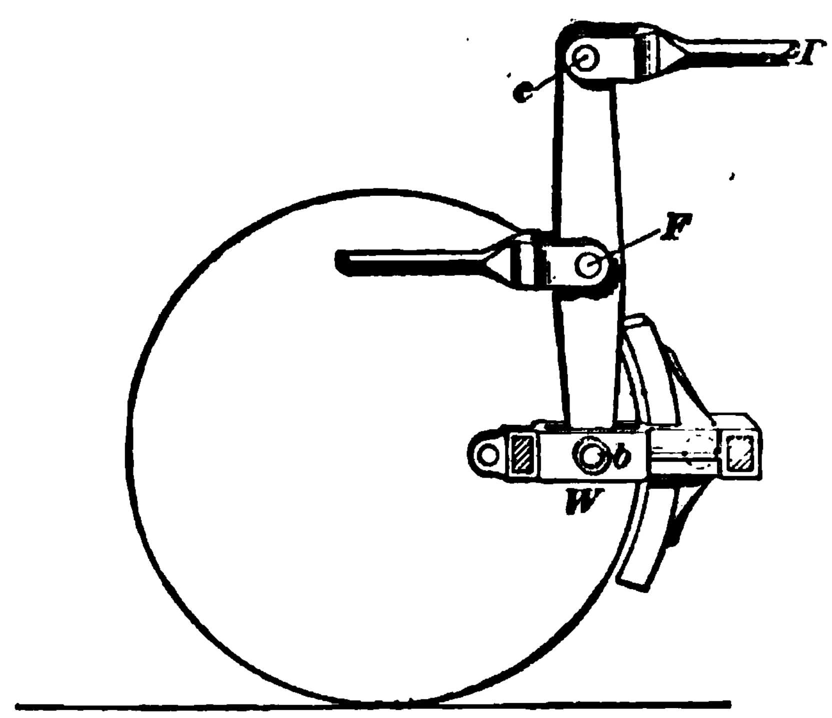


FIG. 7.

56. Classes of Levers.—Levers are divided into three classes, depending on the relative positions of the fulcrum and the points of application of the power and the weight.

In levers of the first class, Fig. 3, the fulcrum F is between the points of application of the power P and weight W. Fig. 7 represents a car-truck lever of this class applied to a car-truck wheel.

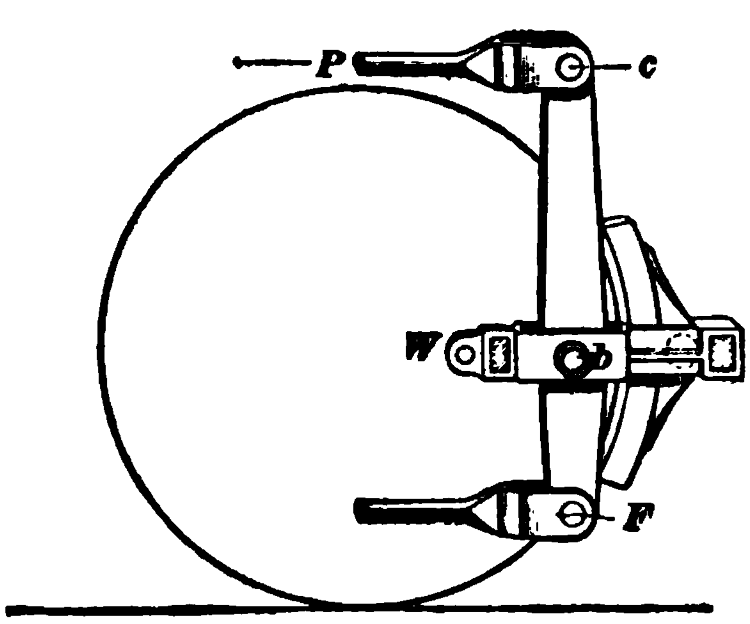


FIG. 8.

In levers of the second class, Fig. 4, the weight W is between the fulcrum F and power P. This class is represented in Fig. 8, as applied to a car-truck wheel.

In levers of the third class, Fig. 5, the power P is between the fulcrum F and the weight W. This class is represented in Fig. 9, as applied to a car-truck wheel.

57. The Weight Sustained by the Fulcrum.—The force exerted on the fulcrum of a lever can be calculated by

assuming that the fulcrum has changed places with either the power P or the weight W, and then using the proper equation. For instance, in example 1, Art. **54**, it was found that a force of 500 pounds at P would balance 1,000 pounds at W, the lever arms being 20 inches and 10 inches, respectively. Now, to find the force sustained at F, assume the fulcrum to have changed places with W. The power arm in this case would be $20 + 10 = 30$ inches long, while the weight arm would remain the same as before, or 10 inches. In this case,

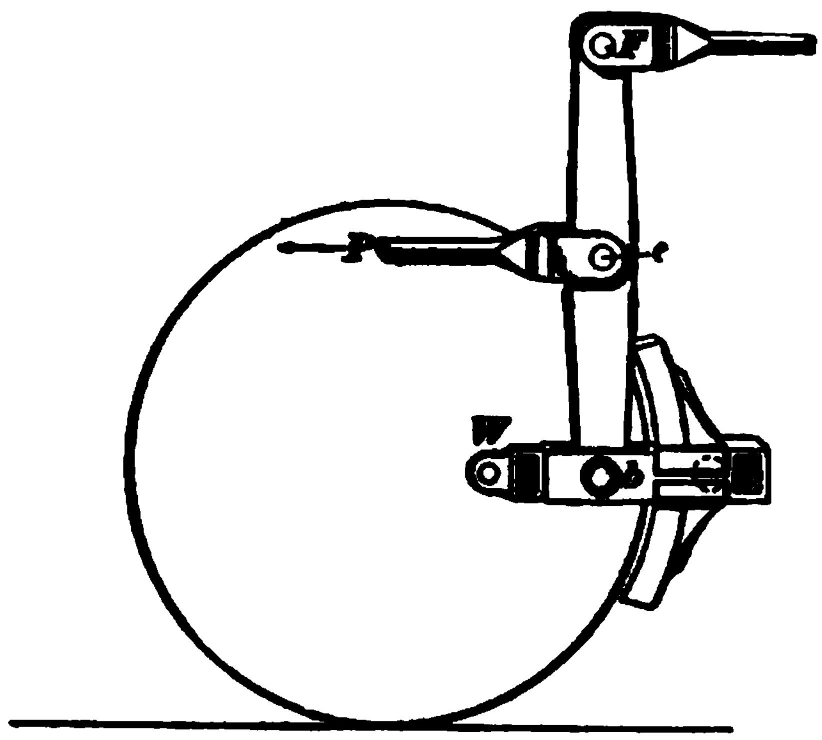


FIG. 9.

$$W = \frac{P \times Fc}{Fb} = \frac{500 \times 30}{10} = 1{,}500 \text{ pounds.}$$

This, it will be noticed, is equal to the sum of the power P and the weight W.

If this method is applied to the three classes of levers, it will be found that (1) the pressure on the fulcrum of a lever of the first class is equal to the sum of the power and the weight, (2) the pressure on the fulcrum of a lever of the second class is equal to the difference between the weight and the power, while (3) the pressure on the fulcrum of a lever of the third class is equal to the difference between the power and the weight.

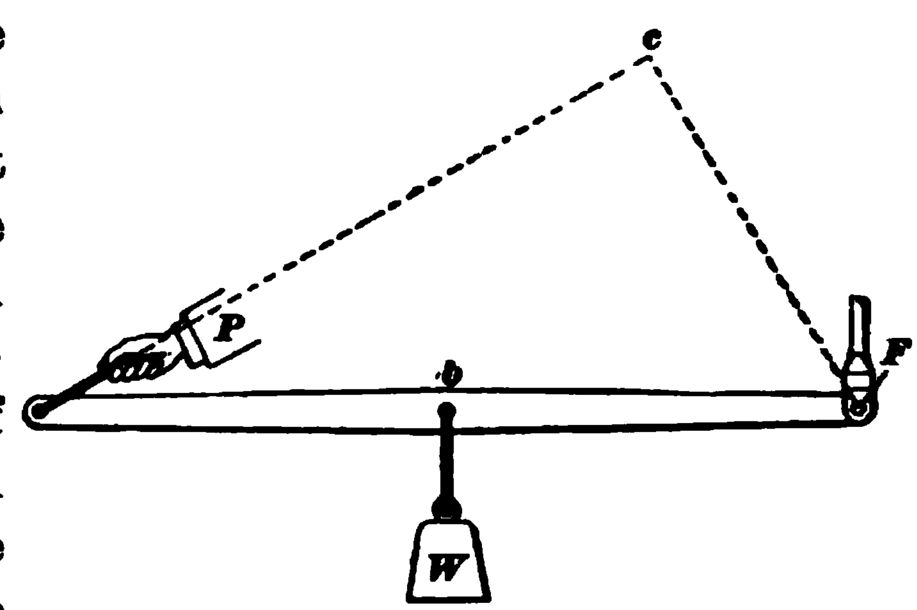


FIG. 10.

58. Bent Levers.—All rules and equations that apply to the straight lever apply equally well to the bent lever, if care is

taken to determine the true or virtual lengths of the lever arms. In the case of a straight lever with the forces acting at right angles to it, the arms may be measured along the lever itself; in all other cases [such as when (1) the forces are parallel but act at an angle to the lever, (2) the forces do not act parallel to each other, or (3) when the lever is bent], the weight arm or power arm must be taken as *the perpendicular distance from the fulcrum F to the line of direction in which the weight or power acts.*

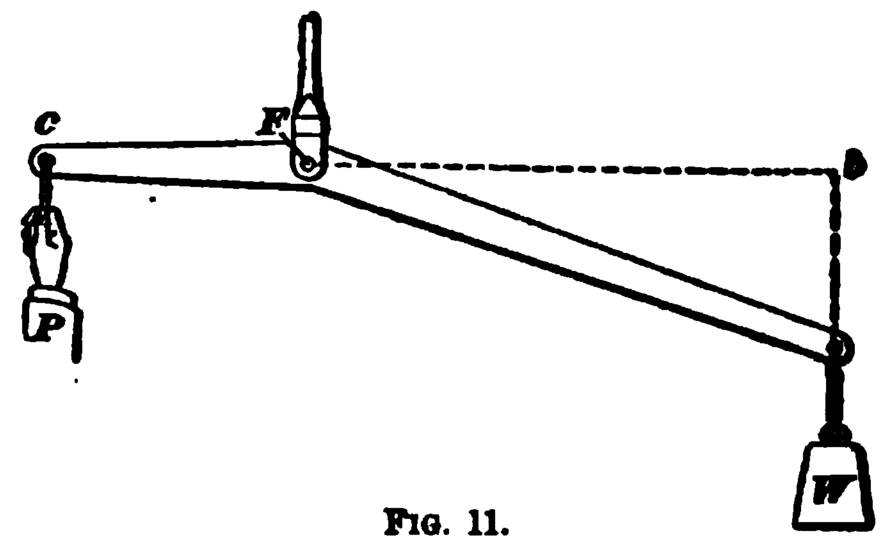


FIG. 11.

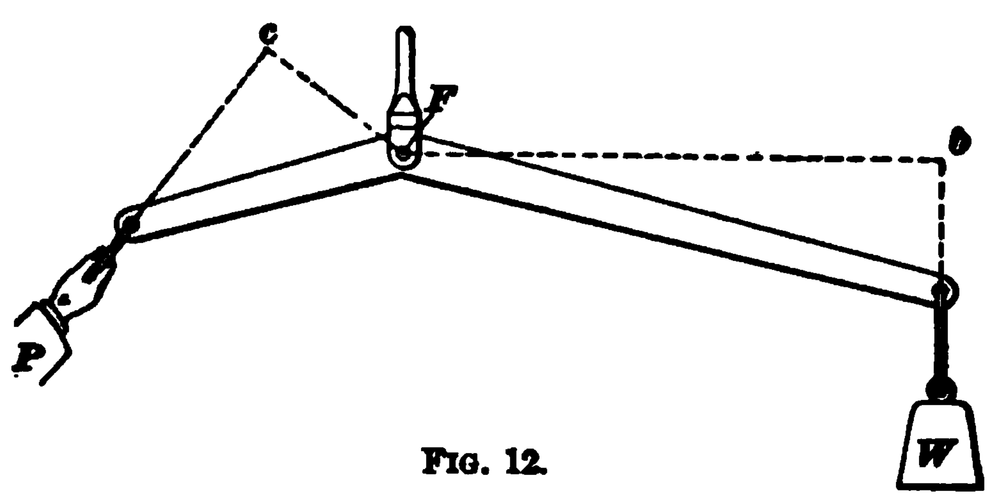


FIG. 12.

Figs. 11, 12, and 13 represent different styles of bent levers. In each case the power arm is repesented by the line Fc, the weight arm being represented by the line Fb. Fig. 10 is dealt with in the same way.

COMPOUND LEVERS.

59. Description.—A compound lever is a combination of simple levers so arranged that when a power is applied to the first lever it actuates all the others and causes a force to be exerted by the last lever of the combination. When a force is applied to the first lever, it exerts a force that is applied to the second lever; the force exerted by the second lever is applied to the third; and so on.

Such a lever is shown in Fig. 14, in which there are three simple levers; the weight arm of the first is connected to the power arm of the second, and the weight arm of the second to the power arm of the third. It will be seen that by applying

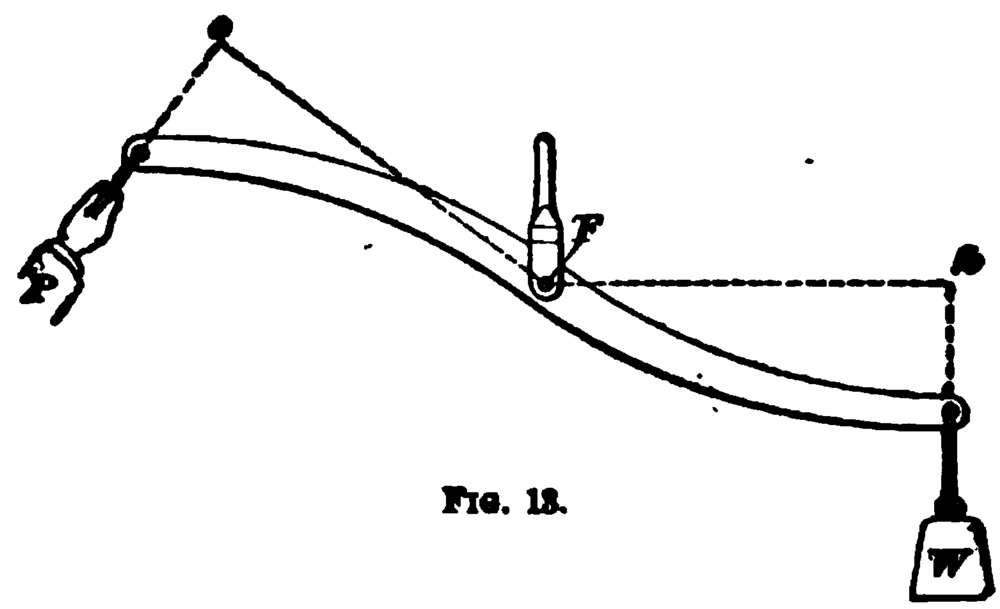


FIG. 13.

sufficient power at *P* to operate the first lever, the others will also be operated, and the weight *W* of the third lever will be raised.

It will be noticed, also, that the force exerted by the end of the weight arm of the first lever is the power applied to the second, and the force exerted by the second is the power applied to the third, and so on for any number of levers.

60. Law of the Compound Lever.—The law that governs the compound lever may be stated as follows: *The*

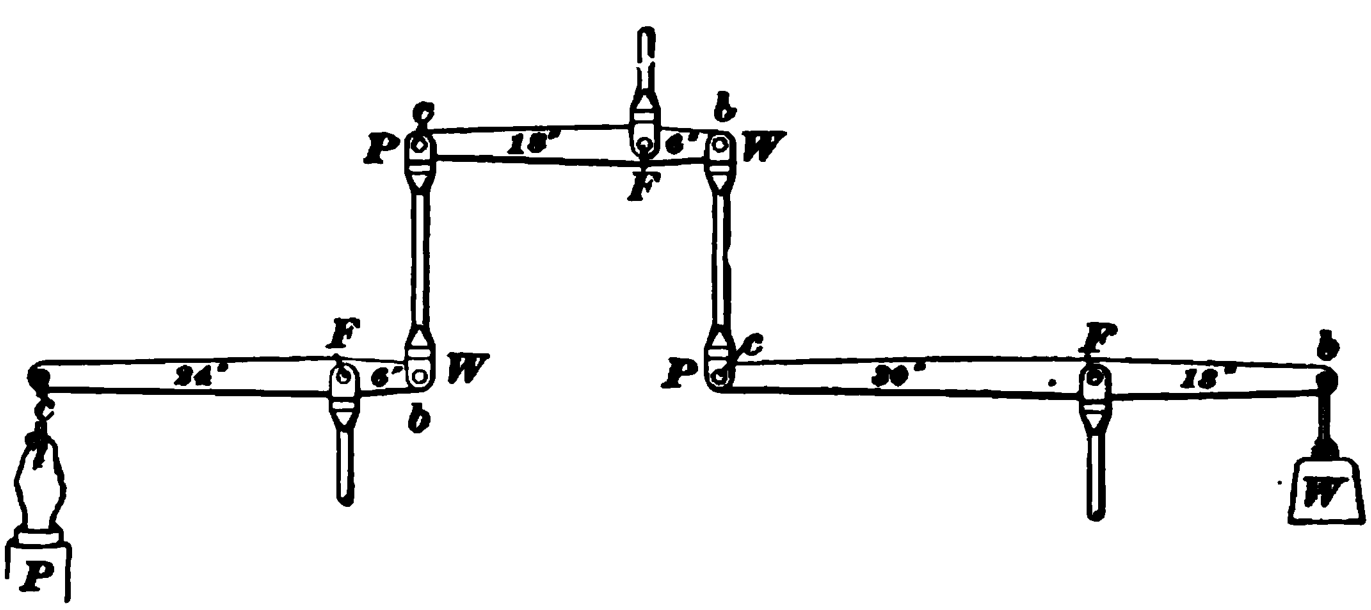


FIG. 14.

power P multiplied by the product of the power arms of all the component simple levers is equal to the weight W multiplied by the product of the weight arms of all these levers.

From this law the following rules may be deduced:

Rule III.—*The power P that must be applied to a compound lever to balance a given weight or produce a given pressure W, may be found by multiplying the product of the weight arms of all the simple levers by the weight, and dividing this by the product of the power arms of all these levers.*

EXAMPLE.—How much power must be applied at P, Fig. 14, to balance 1,000 pounds at W?

SOLUTION.—The weight arms of the levers are 6, 6, and 18 inches, and the power arms 24, 18, and 30 inches, respectively. Hence, from rule III, the power

$$P = \frac{6 \times 6 \times 18 \times 1{,}000}{24 \times 18 \times 30} = 50 \text{ pounds. Ans.}$$

Rule IV.—*The weight that a given power will balance, when applied to a compound lever, may be found by multiplying the product of the power arms of all the simple levers by the power, and dividing this by the product of the weight arms of all the levers.*

EXAMPLE.—If a force of 50 pounds is applied at P, Fig. 14, how many pounds will it balance at W?

SOLUTION.—From rule IV it will be found that 50 pounds at P will balance a weight of

$$W = \frac{24 \times 18 \times 30 \times 50}{6 \times 6 \times 18} = 1{,}000 \text{ pounds. Ans.}$$

LAWS OF LEVERS APPLIED TO BRAKE GEARS.

61. In order to apply these laws to any particular system of levers, it is best to make a diagram showing the position of the fulcrums, length of lever arms, and the line of direction of the forces applied to, or exerted by, the lever. Then, since the force developed by the brake cylinder is generally known, the power exerted by the lever can be readily found by applying the proper rules or formulas.

To illustrate the application of the laws of levers to actual brake gears, the braking power of the Hodge and the Stevens systems of car-brake levers, and of the cam and the equalized types of driver brakes will be determined.

62. The Hodge System.—A diagram of this system is shown in Fig. 15. It will be seen to consist of two compound levers operated by the same brake cylinder, each compound lever consisting of four simple levers. The first of these is called the **cylinder lever**; the second, the **floating lever**; the third, the **truck live lever**; while the fourth is called the **truck dead lever.** The fulcrum of each lever is marked F, and the points at which the power and weight are applied are marked P and W, respectively. The right and left cylinder levers are of the first and third classes, respectively; the floating levers are of the third class; while the truck live levers and truck dead levers are of the first and the second classes, respectively. The brake cylinder is assumed to exert 4,700 pounds pressure in an emergency application.

Calculating the Power of the Hodge System.—To calculate the power applied to the brake shoes, it is now simply a question of using the proper rules for the separate levers. For the first, or cylinder lever, $P = 4,700$; therefore,

$$W = \frac{4,700 \times 15}{15} = 4,700 \text{ pounds},$$

and this is the force applied to P of the floating lever.

The pressure on the fulcrum F of the cylinder lever is equal to the sum of P and W, or 9,400 pounds (see Art. **57**). P of the floating lever is 4,700, as already remarked; therefore,

$$W = \frac{4,700 \times 18}{36} = 2,350 \text{ pounds},$$

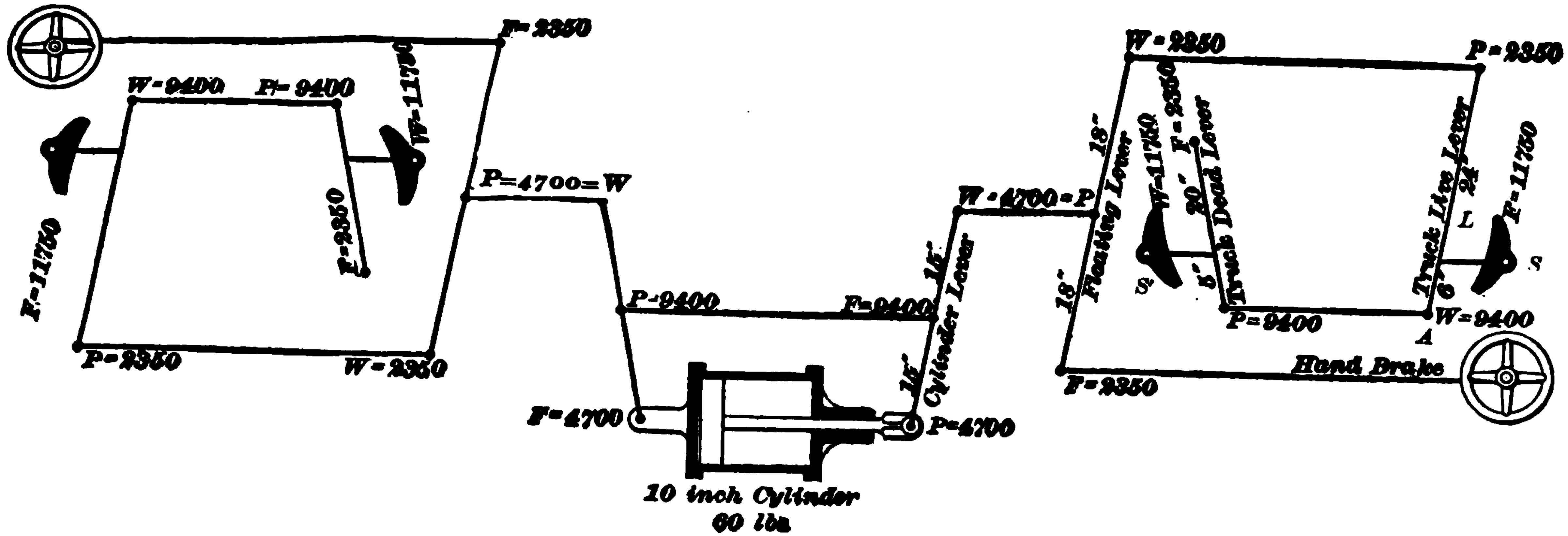
and the pressure on F of this lever is $4,700 - 2,350 = 2,350$ pounds. P of the truck live lever is 2,350 pounds; therefore,

$$W = \frac{2,350 \times 24}{6} = 9,400 \text{ pounds},$$

and the force applied to the wheels at F is $9,400 + 2,350 = 11,750$ pounds. P of the truck dead lever is 9,400; hence,

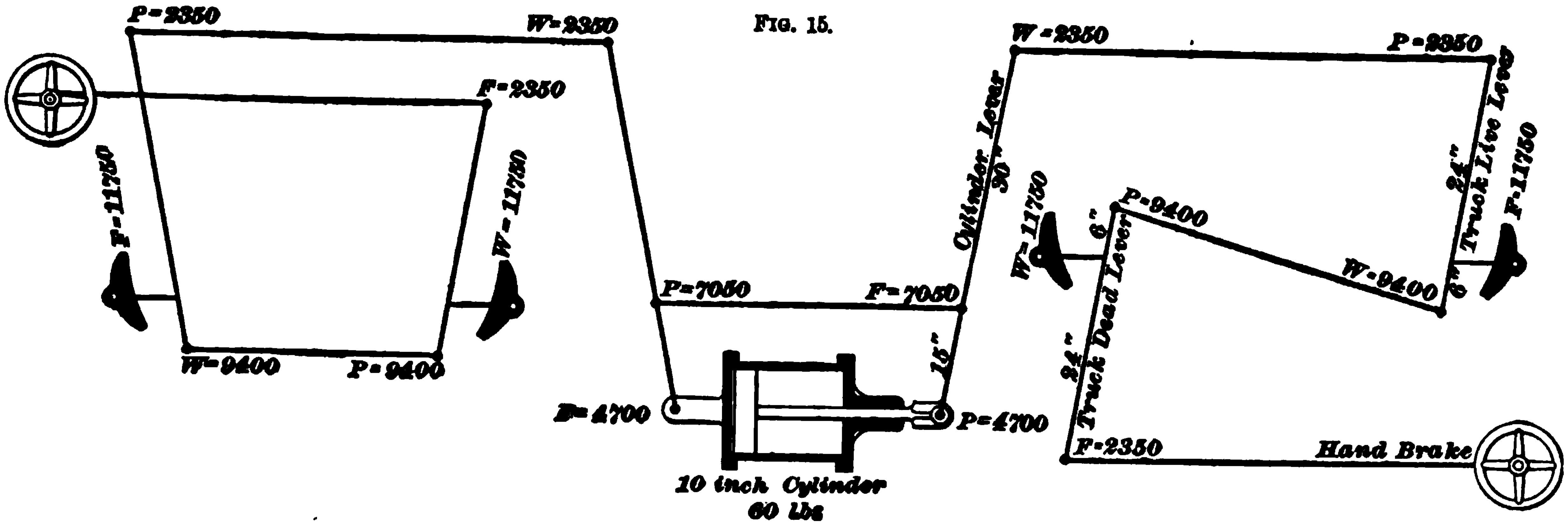
$$W = \frac{9,400 \times 25}{20} = 11,750 \text{ pounds},$$

the force applied to the wheels, while the force exerted at the fulcrum F is $11,750 - 9,400 = 2,350$ pounds.



F=2350
W=9400
P=9400
W=11750
P=4700=W
F=11750
F=2350
P=9400
F=9400
P=2350
W=2350
F=4700
P=4700
10 inch Cylinder
60 lbs
W=4700=P
15"
Cylinder Lever
15"
18"
Floating Lever
18"
W=2350
P=2350
W=11750
F=2350
30"
Truck Dead Lever
5"
P=9400
Truck Live Lever
24
L
F=11750
6"
W=9400
A
S
Hand Brake
F=2350

FIG. 15.



P=2350
W=2350
F=2350
F=11750
W=11750
P=7050
F=7050
W=9400
P=9400
F=4700
P=4700
10 inch Cylinder
60 lbs
15"
Cylinder Lever
30"
W=2350
P=2350
Truck Live Lever
24"
F=11750
P=9400
W=9400
6"
W=11750
6"
Truck Dead Lever
24"
F=2350
Hand Brake

FIG. 16.

The calculations for the left-hand compound lever are made in the same way, beginning with 9,400 pounds applied to P of the cylinder lever.

63. The Stevens System.—The Stevens system of car-brake levers is shown in diagram in Fig. 16. It will be noticed that in this system there are no floating levers, the cylinder levers being lengthened sufficiently to allow the weight arm to be coupled directly to the truck live lever. It will be noticed, also, that all of the simple levers are of the first class, except the left-hand cylinder lever, which is of the third class, and the two truck dead levers, which are of the second class.

Calculating the Power of the Stevens System.—To calculate the power applied to the brake shoes in this system of levers, proceed as with the Hodge system, bearing in mind what was said in Arts. **56** and **57**. For example, if the brake cylinder exerts a force of 4,700 pounds, a force of

$$\frac{4,700 \times 15}{30} = 2,350 \text{ pounds}$$

will be exerted at W of the cylinder lever, while the force F on the fulcrum will equal $4,700 + 2,350 = 7,050$ pounds. 2,350 pounds applied to P of the truck live lever will cause a force of

$$\frac{2,350 \times 24}{6} = 9,400 \text{ pounds}$$

to be exerted at W, while the force on the fulcrum F (the brake shoes) will be $9,400 + 2,350 = 11,750$ pounds. With a force of 9,400 pounds exerted at P of the truck dead lever, a force of

$$W = \frac{9,400 \times 30}{24} = 11,750 \text{ pounds}$$

will be applied to the brake shoes, while the fulcrum F will be subjected to a force of $11,750 - 9,400 = 2,350$ pounds. The force applied to the other brake shoes can be found in a similar manner.

64. Outside Equalized Brake.—This type of brake was illustrated in Fig. 2, Art. **52**, and a diagram of it, as applied to

an engine having four pairs of drivers, is given in Fig. 17. In a brake of this kind, the levers are so proportioned that the braking power developed at the brake cylinder is distributed equally among the drivers, the force applied to the different brake shoes being maintained equal; hence, the brake is said to be an **equalized brake.**

In the figure, the cylinder lever is of the first class, while the others are of the third class, the relative lengths of the lever arms being given in each case. The total force developed in the brake cylinder is, say, 7,000 pounds. This will cause a force of

$$\frac{7{,}000 \times 5}{1} = 35{,}000 \text{ pounds}$$

to be exerted at P of lever A, which in turn will cause a force of

$$W = \frac{35{,}000 \times 4}{5} = 28{,}000 \text{ pounds}$$

to be exerted at P of lever B. The force applied at the fulcrum (brake shoes) of lever A is $35{,}000 - 28{,}000 = 7{,}000$ (see Art. 57). 28,000 at P of lever B will exert at P of lever C, a force of

$$W = \frac{28{,}000 \times 3}{4} = 21{,}000 \text{ pounds,}$$

and a force of $28{,}000 - 21{,}000 = 7{,}000$ pounds will be exerted at the fulcrum (brake shoes) of lever B. A force of

$$W = \frac{21{,}000 \times 2}{3} = 14{,}000 \text{ pounds}$$

will be exerted at P of lever D, while $21{,}000 - 14{,}000 = 7{,}000$ pounds will be exerted on the shoes of lever C. 14,000 pounds at P of lever D will exert a force of

$$W = \frac{14{,}000 \times 1}{2} = 7{,}000 \text{ pounds}$$

at the shoes, and $14{,}000 - 7{,}000 = 7{,}000$ pounds at the fulcrum F.

For an engine having two pairs of drivers, the end W of the cylinder lever would be connected at P of lever C, and levers A and B would not be used. A force of 21,000 pounds would have to be exerted by the cylinder lever to give 7,000 pounds

at each brake shoe, so that if the same size cylinder were used the power arm of the cylinder lever would have to be three times as long as the weight arm.

On an engine having three pairs of drivers, the cylinder lever would be connected to the lever *B*, and would have to exert 28,000 pounds to give 7,000 pounds at each brake shoe; hence, if the brake cylinder were of the same size as above, the power arm of the cylinder lever would have to be four times as long as the weight arm.

BRAKE POWER.

PRESSURES APPLIED TO BRAKE SHOES.

65. In Art. **42** the statement was made that if the frictional resistance exerted between the wheel and the shoe were greater than that exerted between the wheel and the rail, the wheel would slide. With a good rail, these frictional resistances will be practically equal when the force applied at the brake shoe is equal to the pressure of the wheel on the rail, so that the force applied to the brake shoe must be less than the pressure of the wheel on the rail, to insure the wheel against slipping when used under the varying conditions of service. Practical experience has demonstrated that the best results will be obtained by the use of the following as *the maximum safe pressures* on the brake shoes in the different classes of service: For passenger cars, $\frac{9}{10}$, or 90 per cent., of the weight on the rail under the wheel when the car is empty; for freight cars, $\frac{7}{10}$, or 70 per cent., of the weight, on the rail when the car is empty; for tenders, 100 per cent., or the entire weight, on the rail when the tender is light; for driving wheels, $\frac{75}{100}$, or 75 per cent., of the weight under the drivers when the engine is ready for the road.

CALCULATION OF BRAKING POWER.

66. The method of calculating the proper braking power to use in any case is as follows: First find the weight on the rail under each wheel, by dividing the entire weight of the empty

car by the number of wheels. Then, if the car is a passenger car, take $\frac{9}{10}$ of this, or, if a freight car, take $\frac{7}{10}$, as the maximum force to be used on each brake shoe. In other words, this is the allowable force per shoe; therefore, the total brake force can be found by multiplying this amount by the number of wheels that are fitted with brakes, and from this the proper proportion of brake levers can be determined.

The sizes of brake cylinders that are used on cars and tenders of different weights are as follows: 6-inch brake cylinders are used on freight cars having a light weight of 15,000 pounds or less; 8-inch cylinders on tenders of 35,000 pounds light weight or less, and also on freight cars whose light weight is between 15,000 and 40,000 pounds; 10-inch cylinders on tenders of over 35,000 pounds light weight, and also on passenger cars of 50,000 pounds or less; 12-inch cylinders on passenger cars whose light weight is between 50,000 and 70,000 pounds; and 14-inch cylinders on passenger cars of over 70,000 pounds.

EXAMPLE.—What is the maximum braking power that should be allowed at each brake shoe of a 72,000-pound passenger car having 6-wheeled trucks, 4 wheels only of each truck being supplied with brakes? Also, what will be the total braking force?

SOLUTION.—If this car weighs 72,000 pounds and has 12 wheels, there will be a pressure of $\frac{72,000}{12} = 6,000$ pounds on the rail under each wheel; hence, the highest allowable braking force per wheel should be $.9 \times 6,000 = 5,400$ pounds. The total allowable braking force of the car, therefore, will be $8 \times 5,400 = 43,200$ pounds, since only 8 wheels are braked.

67. Force Exerted in the Brake Cylinder.—The total allowable braking force should not be exceeded when a full application of the brakes is made, since at such times it is especially important that no wheels slide, as a sliding wheel exerts but little retarding force. For this reason, the braking power is calculated on the assumption that, in a full-emergency application with the New York air-brake equipment, 50 pounds pressure is obtained in the brake cylinder with a quick-action brake, and 50 pounds with a plain triple.

The total force in pounds that a brake cylinder will develop when subjected to 50 pounds pressure per square inch has been calculated for several sizes of cylinders, and the results tabulated as shown in the accompanying table.

FORCE EXERTED IN BRAKE CYLINDER.

Size of Cylinder. Inches.	With 50 Lb. Pressure.
6	1,400
8	2,500
10	3,900
12	5,600
14	7,700

The force exerted in a brake cylinder is found by multiplying the area of the piston in square inches by the pressure per square inch in the cylinder. Thus, if the piston has an area of 154 square inches, it will develop a force of $154 \times 50 = 7,700$ pounds under a 50-pound pressure.

The area of the piston may be found by multiplying the diameter of the piston in inches by itself, and by 11, and dividing the product by 14. Thus, the area of a 10-inch piston is

$$\frac{10 \times 10 \times 11}{14} = 78\tfrac{1}{2} \text{ square inches, about.}$$

By calculating the area of the piston for different sizes of cylinders, it is found that the piston of a 6-inch cylinder has an area of 28¼ square inches; that of an 8-inch cylinder an area of 50¼ square inches; a 10-inch piston, 78½ square inches; a 12-inch piston, 113 square inches; and a 14-inch piston, 154 square inches.

THE NEW YORK AIR BRAKE.

(PART 4.)

TRAIN AIR-SIGNALING SYSTEM.

GENERAL ARRANGEMENT OF APPARATUS.

1. The general arrangement of the train air-signaling apparatus on an engine, tender, and passenger car is shown in Figs. 1 and 2. This system has gradually taken the place of the old bell-cord-and-gong method of signaling on passenger trains, on account of the ease and certainty with which signals can be transmitted to the engineer from any part of the train.

The engine, tender, and each of the cars are piped with a $\frac{3}{4}$-inch pipe, which is connected between cars by means of hose, so that when all the hose is coupled, the signal-pipe line extends throughout the entire train.

A *car discharge valve*, Fig. 1, is provided on each car. This is usually located outside the car above the door, as shown in the figure, and is piped to the train signal pipe. Sometimes, however, it is placed inside the car above the door, to guard against the valve being clogged in winter. The former position is preferable, however, as the chances of clogging are small, and the annoyance caused by the sharp sound of discharging air every time the valve is opened to make signals is avoided.

A signal cord is attached to the lever of the discharge valve, and one end extends across the platform and is fastened in a suitable manner to the hood, while the other end extends through the car and is fastened to the hood on the other end of the car. This cord enables the discharge valve to be operated from any part of the car.

The air-signal apparatus on the engine, Fig. 2, consists of the *signal valve*, *signal whistle*, and *pressure-reducing valve*. A $\frac{1}{2}$-inch pipe leads from the main reservoir to the reducing valve, and thence to the signal pipe. Another $\frac{1}{2}$-inch pipe connects the

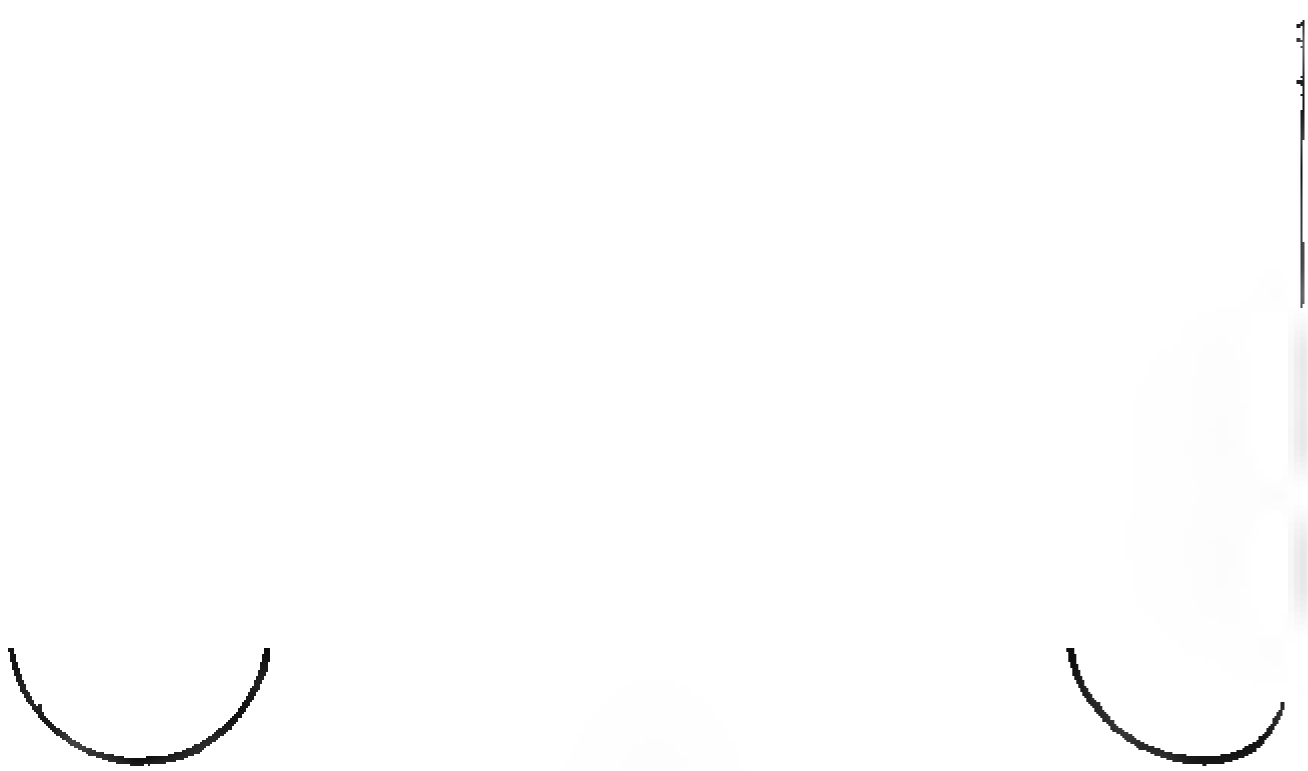


FIG. 1.

signal pipe with the signal valve, from which a $\frac{1}{4}$-inch pipe leads to the whistle. Air from the main reservoir can thus pass through the pressure-reducing valve and thence into the signal pipe and signal valve, but at a reduced pressure. A pressure of 40 pounds is usually maintained in the signal

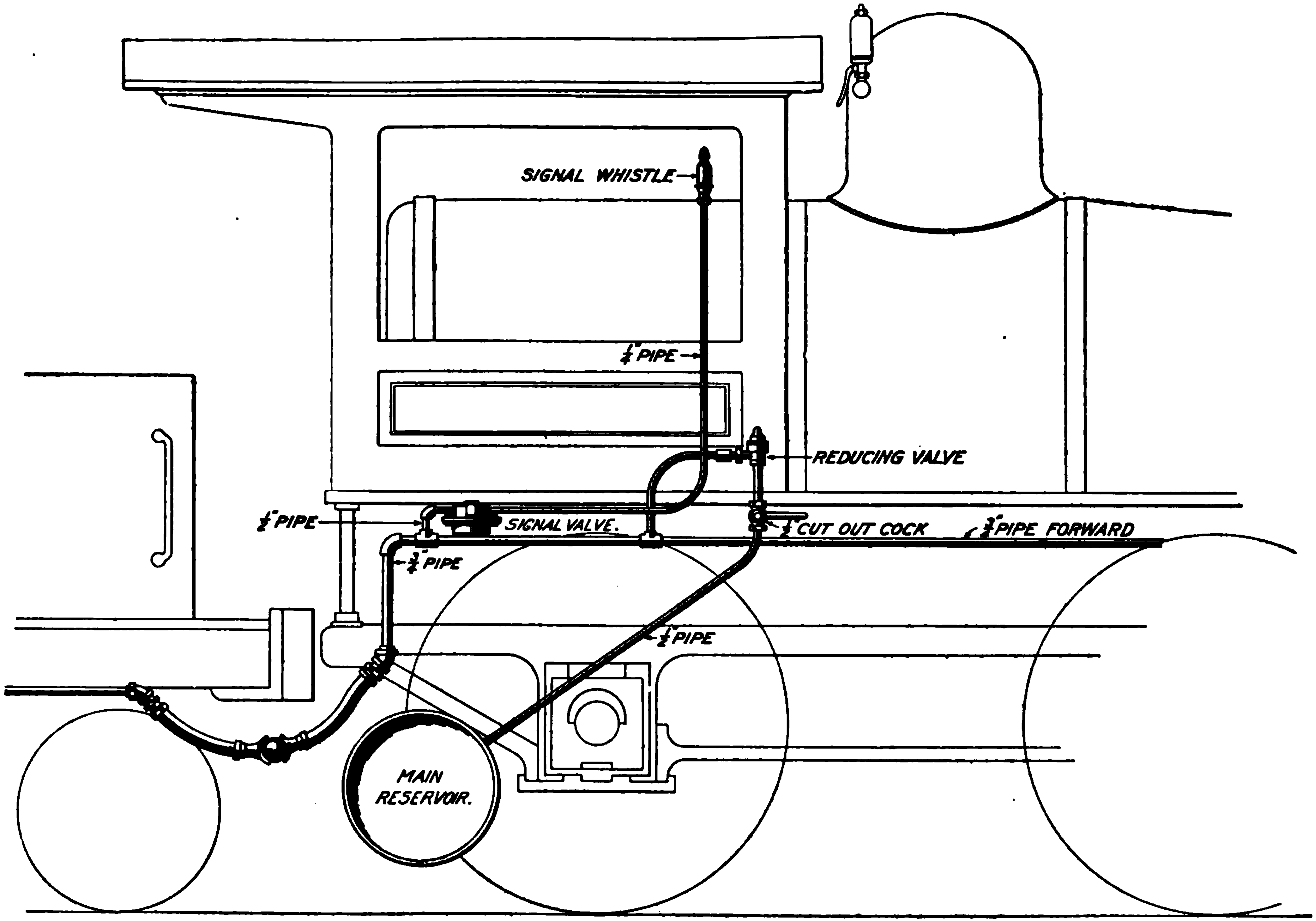

SIGNAL WHISTLE
$\frac{1}{4}$" PIPE
REDUCING VALVE
$\frac{1}{4}$" PIPE
SIGNAL VALVE.
$\frac{1}{4}$" CUT OUT COCK
$\frac{3}{4}$" PIPE FORWARD
$\frac{3}{4}$" PIPE
$\frac{1}{2}$" PIPE
MAIN RESERVOIR.

FIG. 2.

system, and the duty of the reducing valve is to diminish the pressure from 90 pounds (main-reservoir pressure) down to the required pressure for use in the signal system.

Formerly the pressure-reducing valve was frequently screwed directly into the top or end of the main reservoir, but experience has shown that much better results are obtained by placing this valve in the cab of the locomotive, in which place it is much better protected from dirt and from freezing.

The **signal whistle,** Fig. 3 (a small whistle located in the cab, as close to the engineer as practicable), is piped to the signal valve, as mentioned, and it is the operation of the latter that causes the whistle to blow.

When the conductor wishes to transmit a signal to the engineer, he gives the signal cord in one of the cars a pull. This opens the car discharge valve on that car and allows some of the air in the main signal line to escape to the atmosphere, thus reducing the signal-pipe pressure. The reduction in pressure operates the signal valve on the engine, which, consequently, discharges a small quantity of air through the signal whistle in the cab, thus causing it to sound a short blast. Each time the cord is pulled, the signal whistle gives a blast.

FIG. 3.

DESCRIPTION OF APPARATUS.

SIGNAL REDUCING VALVE.

2. A cross-sectional view of the New York signal reducing valve is shown in Fig. 4. The main-reservoir connection is made at *X*, while a pipe leads from *Y* to the signal pipe. The supply valve *4* regulates the admission of air to the signal system; it is operated by the stem of the diaphragm plate *8* and by the supply-valve spring *10*. *7* is the rubber

diaphragm; *6*, the diaphragm ring; and *9*, the regulating spring. In this valve the spring *9* is made strong enough to just resist a pressure of 40 pounds per square inch in chamber *B*. The outlets *e*, *e* in the cap *8* prevent air (due to leakage) from accumulating back of the piston and piston stem and rendering the valve inoperative.

Y

X

FIG. 4.

3. Operation of Valve.—The operation of this valve is as follows: The spring *9*, acting on the diaphragm plate *8*, causes the stem of plate to hold the supply valve *4* from its seat, so that main-reservoir pressure entering at *X* is free to pass through the passages *2*, *2*, past valve *4* and into chamber *B*, and thence through the outlet *Y* to the signal pipe. This increases the pressure in the signal pipe and chamber *B* until it reaches 40 pounds per square inch, when the diaphragm *7* and plate *8*

are forced upwards against the action of the spring *9*. The supply-valve spring *10* then forces the supply valve *4* to its seat, and prevents the further passage of air from the main reservoir to the signal pipe. As long as the pressure in chamber *B* remains at 40 pounds, spring *9* will be compressed and the supply valve will remain closed. Any reduction of pressure in chamber *B*, however, will cause the regulating spring to force the diaphragm downwards, thus forcing the supply valve from its seat and allowing sufficient air to pass to the signal pipe to again raise its pressure to 40 pounds, when the supply valve will close. The valve has no regulating nut by means of which the tension of the regulating spring can be adjusted to alter signal-pipe pressure, as the regulating springs are adjusted to 40 pounds before being placed in the valves.

Should the signal-pipe pressure fall below 40 pounds, the tension of the regulating spring may be increased by placing a washer between it and the cap so as to compress it more; but the better plan is to put in a new spring, properly adjusted, which may be quickly and easily done.

FIG. 5.

The adjustment of the reducing valve should be such that the lift of the supply valve *4* is $\frac{3}{16}$ inch.

CAR DISCHARGE VALVE.

4. A sectional view of the car discharge valve is shown in Fig. 5, in which *3* is the discharge valve, and *4* the discharge-valve spring that holds this valve up against its seat. *5* is the lever, or handle, to which the signal cord is attached, while *6*, *6*

are stop-pins. There is a union connection at *a* to which the branch pipe from the signal pipe is connected, while the exhaust port *b* leads to the atmosphere.

5. Operation of Valve.—When the signal cord on either side of the discharge valve is pulled, the lever *5* is caused to strike the stem of the discharge valve *3* and force the valve from its seat. Air from the signal pipe then passes up through the branch pipes and out to the atmosphere through the union connection *a* and the port *b*, causing a reduction in signal-pipe pressure. As soon as the signal cord is released, the spring *4* forces the discharge valve to its seat again and stops the discharge of air from the signal line.

Referring to Fig. 1, it will be seen that the branch pipe to the discharge valve is supplied with a strainer (where it connects with the main signal pipe) and a cut-out cock—the former to prevent dirt from reaching the discharge valve, and the latter to enable the discharge valve to be cut out in case it is disabled. The handle of the cut-out cock stands parallel with the pipe when the discharge valve is cut out, and at right angles to it when cut in. Also, the cut-out cocks in the signal pipe on either side of the signal hose are closed when the handles stand parallel with the pipe, and open when at right angles to it.

THE SIGNAL VALVE.

6. The signal valve, Fig. 6, is located under the footboards of the cab, and may be placed either on the engineer's or the fireman's side. The signal pipe is connected to it at *X*, while a pipe leads from *Y* to the signal whistle. The valve body is divided into two chambers *A* and *B* by the rubber diaphragm *12*, which operates the diaphragm stem *10*. This rubber diaphragm has two disks, one of sheet iron on the top, and one of brass on the bottom, and through these disks there is screwed a brass plug having a small hole bored through it for the passage of air. The valve *10* is held to its seat by gravity, and controls the passage *e* leading to the whistle. A disk is turned on the stem of valve *10* for three uprights* *a*,

*One upright has been removed in the illustration.

to press against and lift the valve from its seat whenever diaphragm *12* rises. The clearance between the uprights *a* and the disk on the stem of valve *10* should not exceed $\frac{1}{100}$ inch.

7. Operation of Valve.—When the signal pipe is being charged, air enters the signal valve at *X*, and, passing through the small port *d*, charges chamber *A*. It also passes through the passage *c c*, and feeds down slowly into chamber *B*, charging

Fig. 6.

this to the same pressure as chamber *A*. The pressures in chambers *A* and *B* and the signal pipe are equal when the pipe is fully charged.

When the signal cord is pulled and a reduction is made in the signal pipe, it causes a reduction of pressure in the signal valve also, but the passage *c c* is very small, and the pressure in chamber *A* above the diaphragm reduces faster than the pressure in chamber *B*, consequently, the diaphragm and uprights *a, a* are forced upwards and raise the exhaust valve *10* from its seat, thus permitting the air in chamber *A* to flow into the passage *e* leading to the whistle, which causes the whistle to give a blast.

The same reduction of pressure that operates the signal valve also opens the reducing valve, which then allows pressure from the main reservoir to flow into, and raise the pressure in, the

signal pipe. This increase of pressure, following immediately after the reduction in the signal valve, increases the pressure in chamber *A* faster than in chamber *B*, thus forcing the diaphragm downwards, and permitting the valve *10* to close the passage *e*, thus stopping the blast of the whistle.

SIGNALING.

8. In transmitting signals by means of the air-signaling system, certain precautions must be observed in order to obtain good results. For each blast of the whistle, the car discharge valve should be held open just long enough to reduce the pressure in the signal pipe clear up to the signal valve on the engine, when it should be closed. It should then be allowed to remain closed until the pressure has equalized throughout the system, before it is again opened to transmit another signal. If the discharge valve is opened a second and, possibly, a third time before the whistle has ceased to blow, due to the first reduction, the whistle will give one long blast instead of two or three short ones, as intended. If it is opened a second time before the pressure has fully equalized in the signal pipe, the whistle will give a blast after each discharge, but the last blast will be weak on account of the pressure being less than 40 pounds.

In transmitting signals, the best results will be obtained if the car discharge valve is allowed to remain closed from 2 to 3 seconds between blasts, depending on the length of the train. In other words, for each blast, pull the signal cord straight downwards and hold the discharge valve open for 1 second; then allow from 2 to 3 seconds for the pressure to equalize throughout the signal pipe before it is again opened for another blast.

DEFECTS IN THE SIGNALING SYSTEM.

9. Although there are but comparatively few parts in the air-signaling system, it requires good judgment to locate defects that cause incorrect signals to be given. Also, it should be borne in mind that it is not so much the *amount* of the reduction as the *rapidity* with which it is made, that causes the whistle to blow.

SIGNAL SYSTEM FAILS TO CHARGE.

10. If it is found that no air passes into the signal pipe, first see whether the cocks on each side of the hose between the tender and train have been opened. If so, the lining in the hose may be loose and blocking the passage; or, if the weather is cold, the signal pipe on the engine or tender may be stopped up with ice, or the reducing valve, if improperly located, may be frozen up.

IMPROPER EXHAUST FROM DISCHARGE VALVE.

11. If no exhaust occurs at the discharge valve when the signal cord is pulled, the signal pipe being properly charged, the trouble may be due to the cut-out cock, Fig. 1 (usually placed in the saloon), being turned so as to cut out the discharge valve.

If the exhaust from the discharge valve is weak, it may be due to a low signal-line pressure caused by an improperly adjusted reducing valve, by the reducing valve being partly closed by gum or dirt, or by leaks from the signal line greater than can be supplied by the reducing valve. A number of years ago discharge valves were provided with perforated brass strainers at the union. These strainers sometimes became so closed by dirt and pipe scale that only a faint discharge of air could be obtained when the handle of the valve was pulled. Whenever these strainers are found they should be removed and the modern form of T coupling with strainer inserted at the point where the branch leads from the signal line to the discharge valve.

WHISTLE FAILS TO BLOW.

12. If an exhaust occurs at the discharge valve when the signal cord is pulled, but the signal whistle fails to give a blast, the trouble may be due to the strainer in the T, where the branch pipe connects with the signal pipe, being stopped up (see Fig. 1). In this case, the exhaust may sound all right, since there is considerable air in the branch pipe between the strainer and the discharge valve, but the air in the main pipe cannot get past the strainer fast enough to make a sufficiently

quick reduction to operate the signal valve. If the trouble is not in the strainer, it may be that (1) port *d* of the signal valve is stopped up, in which case no air can enter the valve to charge it; (2) the signal-valve diaphragm is bagged or, possibly, cracked; (3) the bell of the signal whistle is imperfectly adjusted or the bowl is full of dirt; or (4) the whistle is so situated that wind blowing across the bowl prevents it from sounding.

If poor rubber is used in the diaphragm, or if oil gets on it, the rubber will, in time, stretch and bag. In that event, when a signal-pipe reduction is made, the diaphragm will respond to it without raising the valve *10* from its seat, and no blast will result. An overheated air pump also tends greatly to buckle or distort the diaphragm. In some cases the diaphragm cracks, causing chambers *A* and *B* to become directly connected.

WHISTLE GIVES ONE LONG BLAST.

13. If, in transmitting a signal, the whistle simply gives one long blast, it probably is due to the reductions being made too close together, or to dirt on the seat of the disk valve *10*. In the latter case the valve *10* would be held from its seat and a continuous blast would result.

WHISTLE BLOWS WHEN BRAKES ARE RELEASED.

14. If the whistle blows every time the brakes are released, it indicates that there is direct connection between the main reservoir and signal pipe, and that the latter is charged to main-reservoir pressure. This may be due either to valve *4* of reducing valve being held open by dirt on its seat or by there being too much tension in the spring *9*; or to the spring *10* being broken or too short, so that it does not force the valve *4* to its seat.

The reason why the whistle blows when the brakes are released is as follows: Since there is a direct opening between the signal pipe and the main reservoir, air will flow from the former to the latter every time the main-reservoir pressure is reduced in releasing the brakes. This causes a reduction of signal-pipe pressure right at the signal valve, which, if the

opening through the reducing valve is large enough, and the main-reservoir pressure is reduced sufficiently fast, will operate the signal valve and cause the whistle to give a blast. If the opening through the reducing valve is small, the whistle may not sound if the signal pipe is long, whereas it may do so on a very short train or on a lone engine.

Main-reservoir pressure in the signal pipe can be detected from the train by a stronger discharge of air from the discharge valve when the signal cord is pulled; on the engine it will be indicated by the signal whistle screeching, due to the fact that the bell of the whistle is adjusted for 40 pounds pressure and not for 90.

OTHER DEFECTS.

15. Sometimes the whistle only gives a *weak blast* when the cord is pulled. This may be due to the regulating spring of the reducing valve being too weak, so that there is less than 40 pounds in the signal pipe; the whistle may be full of dirt or be improperly adjusted.

The bell of the signal whistle, Fig. 3, may be adjusted by loosening the locknut *n* and unscrewing or screwing up the bell, as the case may require.

If, in the signal valve, Fig. 6, the valve *10* is held from its seat by dirt, there will be a constant blow at the whistle.

A *leaky* car discharge valve, due either to dirt on the seat of the valve or to a defective valve seat, is a common source of trouble. If dirt on the valve seat is the cause of the leak, opening and closing the valve will sometimes remedy it by blowing the dirt off.

TERMINAL TEST OF AIR-SIGNAL APPARATUS.

INSPECTING THE SIGNAL SYSTEM.

16. In making up a train, the air-signal hose should be connected up at the same time the train-pipe hose is, and all the signal-pipe cocks opened except the rear cock on the last car of the train; this should be closed, and the signal hose hung up properly. While looking the train over for leaks, the signal

hose and couplings and also the car discharge valves should be inspected to see if they are in good condition. If a discharge valve is found to be leaking, jerk it open a few times; if this does not remedy the leak, the valve will have to be reseated. If a discharge valve is found to be defective while on the road, it should be cut out by closing the cut-out cock in the branch pipe. The conductor should then be notified, and he should report the same for repairs at the end of the run.

In testing the signal system, signals should be transmitted from the rear car of the train, from a car in the center, and also from the car next to the engine.

TESTING DEVICE.

17. The device about to be described has been used very successfully in testing for, and locating, defects in the signaling apparatus, and it ought to be more widely used than it is. It consists simply of an air gauge, a signal-line hose, and a small petcock, the cock having a $\frac{1}{8}$-inch hole through its plug. The hose is fitted with a coupling, but has no nipple, the air gauge being connected to its nipple end. A hole is drilled through the coupling into the air space and tapped, and the petcock screwed into it.

When this device is coupled into the signal pipe, the signal-pipe pressure will be indicated by the air gauge, while, by means of the petcock, a reduction of any amount or duration may be made in the signal-pipe pressure.

18. Using the Device.—The **testing device** may be used to determine the condition of the automatic reducing valve, as follows: First connect the device into the signal pipe and charge the latter to standard pressure; then open the petcock wide, make a 10-pound reduction, and note the time required to raise the pressure to standard again. If the pressure rises slowly, it may be that the supply valve does not open sufficiently to admit of its feeding faster, and the valve should be taken down and repaired.

The engine signal apparatus should be tested with the testing device just described as often as convenient. This test should

be made by a person familiar with locating and remedying troubles. The test should never be made by means of the stop-cock on the rear of tender or front end of the engine. Such a test is misleading for the reason that it does not give any assurance that the whistle will blow under service conditions when the engine is coupled to a train. Besides, it is injurious to the diaphragm in the signal valve. In fact, it may be said that with a sudden heavy discharge of air, as from the stop-cock, even a somewhat defective signal valve would respond and cause the whistle to sound, which, under service conditions, it would not do.

TESTING SIGNAL VALVE.

19. To test the signal valve, make a slow gradual reduction of about the same magnitude as the leaks in the train pipe would amount to; then gradually increase the rate of discharge until the signal whistle blows.

If the whistle blows when a slow gradual reduction is being made, it indicates the presence of dirt on the disk of valve *10*, a slow-feeding reducing valve, or possibly both. In this case, the remedy is to clean the valve *10*, which can be easily removed by unscrewing cap nut *20*.

TESTING SIGNAL-PIPE PRESSURE.

20. The following is a method for testing the signal-pipe pressure when no special testing apparatus is available for this purpose: Before starting the pump, place the handle of the engineer's brake valve on lap position, pump up a pressure of 50 pounds in the main reservoir. Now see that the cut-out cocks in the signal pipe at front of engine and rear of tender are closed, and open the angle cock in the train pipe. Move the handle of engineer's brake valve to the running position until main-reservoir pressure commences to reduce rather quickly.

If the whistle blows at any pressure above 40 pounds while the main-reservoir pressure is being reduced, the signal-pipe pressure is too high; if it does not blow until the main-reservoir

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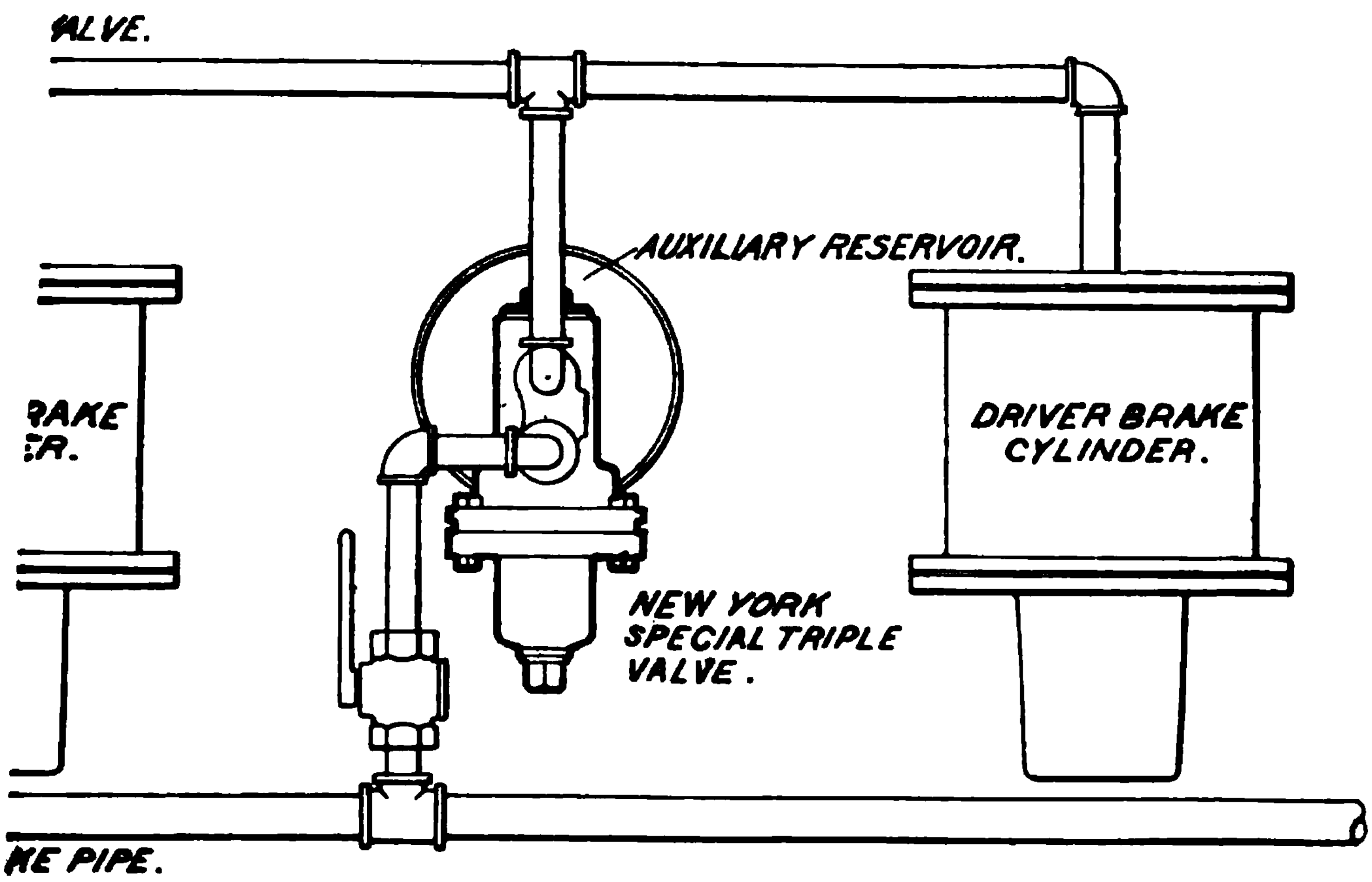
AUXILIARY RESERVOIR.
DRIVER BRAKE CYLINDER.
NEW YORK SPECIAL TRIPLE VALVE.

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pressure is reduced to slightly below 40 pounds, there is the required pressure in the signal pipe; if it fails to blow until main-reservoir pressure falls 5 pounds or more below 40, the signal-pipe pressure is too low.

CONTROL OF HEAVILY LOADED TRAINS ON GRADES.

21. The question of adequate brake power for trains on grades is an important one, especially when the operation of heavily loaded trains of large capacity cars is considered. On medium grades, the quick-action brake with standard pressure has been found quite effective in both passenger and ordinary freight service, but on very steep grades it is difficult and sometimes quite risky to attempt to control heavily loaded trains by means of the quick-action brake alone without the aid of some special device by means of which the braking power can be increased when necessary, to conform more nearly to the load.

NEW YORK HIGH-PRESSURE CONTROL APPARATUS.

FIRST ARRANGEMENT.

22. General Arrangement.—The brake apparatus and its arrangement on the engine and tender is shown in Fig. 7. It will be seen to differ from the ordinary equipment in that the pump governor is replaced by a *duplex governor;* and a safety valve, like that shown in Fig. 10, is connected to the engine and tender-brake cylinders to prevent the cylinder pressure from increasing above 50 pounds per square inch, as it is not considered desirable to increase the pressure in either cylinder above that amount.

Considerable increase in braking power can be obtained by applying brakes to the wheels of the forward truck of the locomotive if it is of the four-wheel class. A separate triple can be

used to operate this brake or by using a *special plain triple* as indicated in Fig. 7, both the driver brake and the front-truck brake can be operated by the same triple.

23. Duplex Governor.—The duplex governor, Fig. 8, differs from the plain single governor in that it consists of two pressure-regulating tops secured to one governor body by means of a Siamese coupling. In the pipe *c* leading to the low-pressure top, there is a cut-out cock for the purpose of cutting out the low-pressure governor.

One of the pressure-regulating tops is adjusted to 70 pounds and the other to 90 pounds. The excess-pressure valve allows 90 and 110 pounds pressure to accumulate in the main reservoir, depending on which governor is controlling the pump. The pressure-regulating tops are the same as the one used on the single governor and described in *The New York Air Brake*, Part 1.

24. Special Triple.—The special triple shown in Fig. 9 is used on all engines equipped with 12-inch or 14-inch brake cylinders, regardless of whether the higher pressure is used or not. It is an ordinary plain triple valve with all its parts and ports somewhat enlarged, to accommodate the larger volume of air that must pass through it.

25. *Construction.*—The parts of the special plain triple valve, as numbered in the figure, are: *1*, the triple body; *2*, the triple head; *3*, the triple slide valve; *4*, the slide-valve spring; *5*, the triple piston; *6*, the triple piston packing ring; *7*, the graduating valve; *8*, the upper cap nut; *9*, the graduating stem; *10*, the graduating spring; *11*, the graduating-stem nut; and *12*, a leather gasket.

The space marked *C* is called the slide-valve chamber; *g* is the exhaust cavity in the face of the slide valve *3*; *k*, the triple exhaust port; *m*, a small feed groove in the piston bushing; and *n*, a groove in the shoulder of the triple piston itself. These grooves *m* and *n* allow air from the train pipe to feed back into the auxiliary reservoir when the triple piston is in release position. The piston *5* is acted on by pressure on both sides

FIG. 8.

FIG. 8.

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of it. The branch pipe from the train pipe connects with the triple at *W*; the pipe leading from the brake cylinder connects at *X*; while the connection to the auxiliary reservoir is made at *Y*. Chamber *C*, as will be evident on studying the figure, is charged with auxiliary pressure, and chamber *B* with train-pipe pressure, the piston *5* marking the line of separation between the two. The piston *5* may be moved up or down by increasing or decreasing the pressure in chamber *B* above or below that in chamber *C*. The packing ring *6* is made a good fit in the bushing, so that when the piston has moved down far enough to cover the groove *m*, air cannot readily leak by it in either direction.

26. *Operation.*—The automatic portion of the mechanism of the special plain triple consists of the slide valve *3*, graduating valve *7*, piston *5*, and graduating stem *9*. A sectional view of the slide valve *3*, showing the graduating valve and ports, is given in view (*d*). The port *w* passes through the slide valve from one side to the other. When the graduating-valve pin *7* is off its seat, auxiliary air can flow through port *w* past the valve and out at *z*. Besides ports *w* and *z*, there is an exhaust cavity *g* in the face of the valve, as seen in view (*a*). The slide valve is surrounded by air at auxiliary pressure, which holds the valve to its seat. The spring *4* is provided to hold the valve to its seat when there is no auxiliary pressure to perform this duty, thus preventing dirt from collecting on the valve seat and affecting the working of the triple. The piston *5* controls the movements of both the slide valve and the graduating valve. The slide valve fits loosely between shoulders on the piston stem, and when the piston moves to either apply or release the brake, it carries the slide valve with it. The graduating pin *7* is connected to the stem of piston *5* by means of a small pin, shown in view (*a*), the place where it enters the pin and stem being shown by dotted lines; thus, the graduating pin is fixed with respect to the piston *5* and moves along with it. The length of the slide valve *3* is purposely made less than the distance between the shoulders on the piston stem, so that the piston in moving downwards

will open, or, in moving upwards, will close, the graduating valve *7* before it moves the slide valve *3*. When the slide valve is in service position, the piston *5* can move up and down far enough (about $\frac{3}{16}$ inch) to operate the graduating valve without disturbing the slide valve.

We thus see that the piston may move a limited distance without moving the slide valve; whereas, the graduating valve, being secured to the piston stem by the small pin referred to on the preceding page, must move with the piston.

The graduating stem *9* is held in position by the graduating spring *10*. When a gradual or service reduction of train-pipe pressure is made, the pressure in chamber *B* is reduced below that in chamber *C*, and auxiliary pressure then moves piston *5* down until its knob *j* touches the graduating stem *9*, when the spring *10* prevents it moving any farther. When a sudden and heavy reduction of train-pipe pressure is made, as in emergencies, a sufficient difference of pressures is established in *B* and *C* to cause piston *5* to move down quickly and compress spring *10*, the piston traveling the whole length of chamber *B* until it bottoms on the leather gasket *12*.

The graduating nut can be removed when desired to drain the triple or to examine the graduating stem and spring. *w* and *z* form one continuous port through the slide valve *3*, as already explained in connection with view (*d*); this port is opened and closed by the graduating valve *7*, and is called the *service*, or *graduating, port*. When the triple is in *service position*, air from the auxiliary reservoir flows through the slide valve by means of this port, thence through the passage *f* and into the brake cylinder.

A cut-out cock *5* is placed in the branch pipe leading to the triple, to cut it out in case of defects to brake apparatus or triple itself.

27. *Action of Parts.*—To apply the brake, it is necessary for a train-pipe reduction to be made. This may be made (1) by the engineer, (2) by the use of the conductor's valve, or (3) by a burst or a heavy leak in the train pipe.

If the engineer makes a reduction of 5 pounds in the train

(a)
Release Position.

(d)

Servi

F

Emergency Position.

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pipe, only 65 pounds will remain in chamber *B*, whereas there will be 70 pounds in chamber *C*, or the auxiliary side of piston *5*. This greater auxiliary pressure will force piston *5* downwards. While being forced down, it first closes the feed groove *m* and unseats the graduating valve 7, allowing auxiliary pressure to enter the slide valve at *w* and pass through to the end of port *z*. The air, however, cannot pass out of port *z* until the slide valve is moved to service position. By the time the graduating valve is unseated and the feed groove *m* closed, the shoulder *13* on the upper end of the piston stem has engaged the slide valve and begun to move it down. As the slide valve moves down, the exhaust cavity *g* is closed to the port *f* leading to the brake cylinder. When the knob *j* touches the graduating stem *9*, the piston *5* is prevented from making any further downward movement. With the triple piston in this position, the service port *z* of the slide valve is directly in front of port *f*. This position of the valve is called the *service position*, and is shown in Fig. 9 (*b*). The graduating valve being off its seat, there is now an open communication between auxiliary and brake cylinder, and air flows from the auxiliary through the ports *w* and *z* in the slide valve, thence through the port *f* and out at *X* into the brake cylinder, where the pressure will force out the brake piston and set the brakes. Just so long as the auxiliary pressure is greater than that in the train pipe, so long will piston *5* be held down and the graduating valve remain unseated; but the auxiliary pressure gradually expands into the brake cylinder, until the pressure in chamber *B* is sufficiently greater than that in chamber *C* to overcome the small friction of the packing ring *6*, and cause piston *5* to move upwards and seat the graduating valve, thereby closing port *w*. The pressure on the train-pipe side of the piston *5* still slightly exceeds that in the auxiliary, but not to such an extent as to overcome the additional friction encountered in moving the slide valve *3*; the piston therefore stops as soon as the graduating valve has been seated. This is called the *lap position* of the triple valve, in which position all ports are blanked. The brakes are now partially set; a further train-pipe reduction will be necessary to apply them any harder.

If another 5-pound train-pipe reduction is made, there will be a pressure of 60 pounds in the train pipe and 65 in the auxiliary. The greater auxiliary pressure again forces the piston down, but in this case the slide valve was already in service position to begin with, and it is only necessary to move the piston down sufficiently to unseat the graduating valve. This is accomplished by the time the knob *j* touches the graduating stem *9*; and once more, by means of the service part of the slide valve, communication is established between the auxiliary and the brake cylinder. The graduating valve is again seated automatically by the piston *5* when the auxiliary pressure becomes a little less than that in the train pipe.

After the slide valve has once been moved down, it remains in service position until the brakes are released. Each reduction of train-pipe pressure causes the brake to set harder, and these reductions may be continued just as long as the pressure in the auxiliary is greater than that in the brake cylinder. When these pressures become equalized, the brake is fully set, and a further train-pipe reduction would be a waste of air. With an 8-inch piston travel, a train-pipe reduction of about 20 pounds will cause a full application of the brakes.

28. *Releasing.*—To release brakes, the engineer allows the pressure stored in the main reservoir to feed into the train line. When the pressure on the train-pipe side of piston *5* is sufficient to overcome auxiliary pressure and the friction of the working parts, the piston is forced upwards to *release position*, carrying the graduating and slide valves with it. In this position, Fig. 9 (*a*), the feed groove *m* is opened, and air from the train pipe feeds through *m* and *n* to recharge the auxiliary. At the same time, the pressure in the brake cylinder escapes through *X*, and ports *f*, *g*, and *k* into the atmosphere.

29. *Emergency Application.*—To apply brakes in an emergency, it is necessary to make a sudden and heavy train-pipe reduction. This sudden reduction causes piston *5* to move down very quickly and, compressing the graduating spring *10*,

to traverse the full length of chamber *B*. In this position, a direct connection is established between the auxiliary and brake cylinder across the upper end of the slide valve *3*, as shown in Fig. 9 (*c*). Auxiliary pressure passes direct into port *f*, and out into the brake cylinder at *X*, without having first to pass through the service ports of the slide valve. As only the large ports are used in *emergency position*, they allow the pressure in the auxiliary and brake cylinder to equalize more quickly than do the smaller ports used in the service position. The brake sets *more quickly* in emergency, with the plain triple, but *not with greater force.*

30. The Safety Valve.—The reducing valve, or safety valve, shown in Fig. 10, consists of a valve body *2*, a cone valve *3* held to its seat by the spring *4*, an adjusting nut *5*, and a cap *6*. The tension of the spring is increased by screwing down, or diminished by unscrewing adjusting nut *5*, but it is usually adjusted to resist a pressure of 50 pounds. The end of the valve *X* is screwed into the brake cylinder, and whenever the pressure in the brake cylinder exceeds that for which it is adjusted, valve *3* is forced from its seat, and brake-cylinder pressure may then reduce through passage *a*, and ports *y*, *y* in the valve body.

FIG. 10

USE OF APPARATUS ON LONG GRADES.

31. When a train fitted with the high-pressure control apparatus is to descend a long grade, the cut-out cock in the governor pipe *c*, Fig. 7, is turned at right angles to the pipe, so as to cut the low-pressure side of the pump governor out of service. Thus, when descending long grades, the main reservoir is charged to 110, and the train pipe to 90, pounds.

The brakes are operated in exactly the same manner as before, the only difference being that the auxiliaries are charged to 90 pounds, and consequently a full-service application of the brakes will result in a brake-cylinder pressure of nearly 65 pounds per square inch instead of 50 pounds.

When grades are exceptionally long and heavy, so that the driver brakes have to be held on hard for a considerable length of time, trouble is generally experienced with the driving-wheel tires heating, the friction between the brake shoe and the wheel generating heat, which expands the tire. On such grades, therefore, the brake known as the *water brake* can be used to good advantage.

TESTS* SHOWING TIME REQUIRED TO OPERATE BRAKE WITH 90 POUNDS TRAIN-PIPE PRESSURE.

Test No.	Time in Seconds Required for Reduction to Travel From Brake Valve to 1st Car.	Time in Seconds Required for Reduction to Travel From 1st Car to 50th Car.	Time in Seconds Required for Reduction to Travel From Brake Valve to 50th Car.
EMERGENCY APPLICATION.			
1	.1360	2.525	2.661
2	.1350	2.532	2.667
Average	.1355	2.528	2.664
SERVICE APPLICATION.			
1	1.502	6.030	7.532
2	1.492	6.536	8.028
3	1.497	6.283	7.780
Average	1.497	6.283	7.780

* Tests made by the New York Air Brake Company.

32. The preceding table shows the time that elapses between the operation of the first and last triples on a 50-car train in both service and emergency applications, and when it is

remembered that the triples move one after the other, they give a very good idea of how rapidly the train-pipe pressure can be reduced in emergencies. When this table is used in connection with speed tables showing the distance traveled in a second at different rates of speed, they give a very fair knowledge of the value of a small fraction of a second in shortening the stops. The time-service test table is given for the sake of comparison.

SECOND ARRANGEMENT.

33. Another arrangement for safely controlling the speed of trains on down grades is shown in Fig. 11. In this arrangement two Siamese couplings are screwed into the body of the brake valve, one into the part of the valve containing main-reservoir pressure, and one into the part containing train-pipe pressure. In other words, one coupling is screwed into the train-pipe gauge connection and the other into the main-reservoir gauge connection of the brake valve.

Two pipes lead from each Siamese coupling; one from the coupling connected to the train-pipe pressure leads to the black-hand side of the air gauge, and the other connects to the low-pressure top of the duplex governor, which is set to stop the pump when 70 pounds pressure has been obtained in the train pipe. This governor top, therefore, controls the pump only when the handle of the brake valve is in full release or running position. One pipe leads from this Siamese coupling, screwed into the main-reservoir gauge connection to the red-hand side of the air gauge, while the other pipe leads to the high-pressure governor top. With this arrangement the high-pressure top is usually set to operate at from 100 to 110 pounds pressure, and the regular governor connection on the brake valve is plugged up.

When the duplex governor and the brake valve is piped in this manner, a high excess pressure may be accumulated in the main reservoir while the brakes are applied and the handle of the valve is in "lap" position, and this increased amount of excess pressure insures the prompt and uniform action of the triples and a quick recharging of the auxiliaries when the

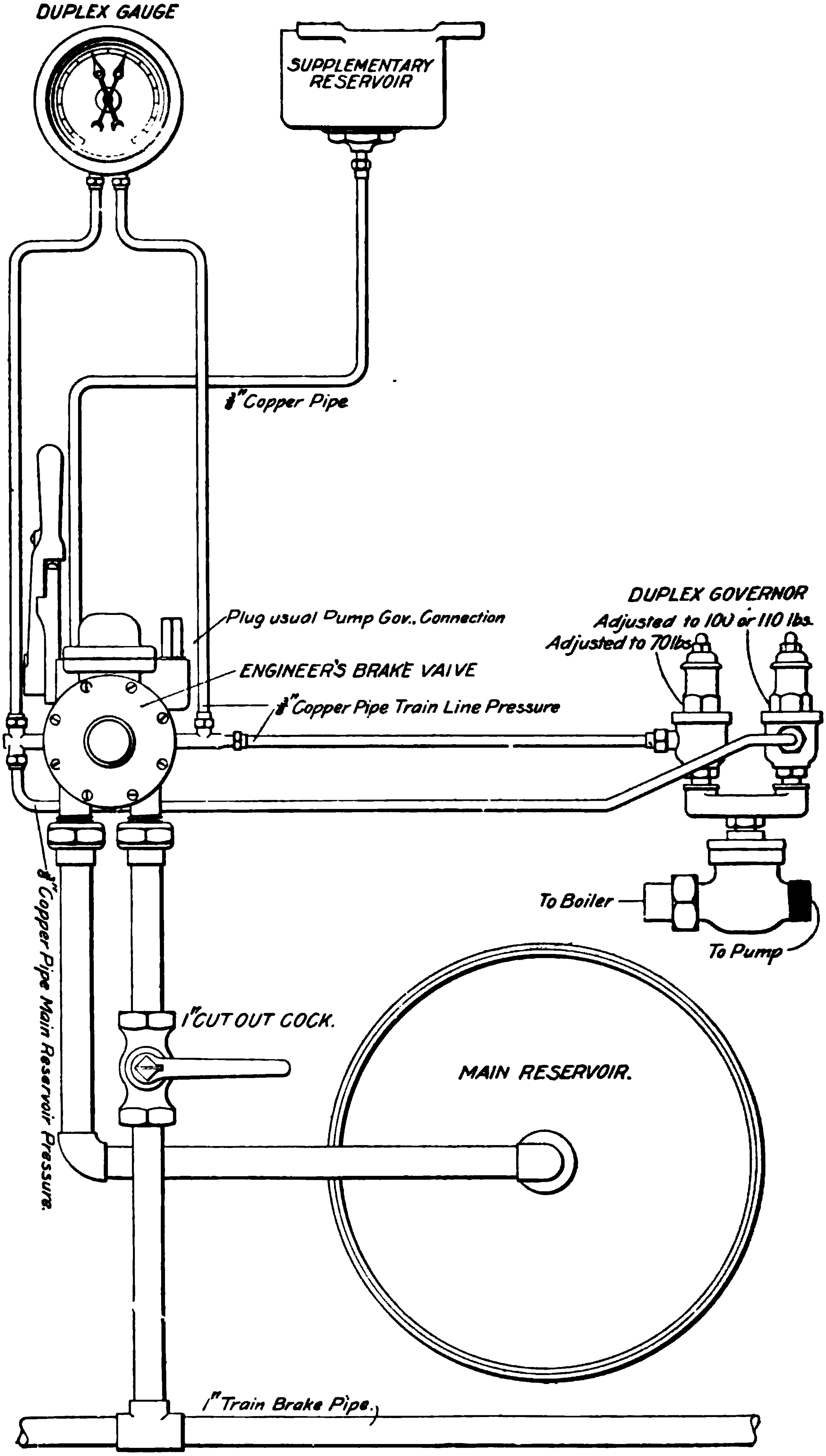
DUPLEX GAUGE
SUPPLEMENTARY RESERVOIR
⅜" Copper Pipe
Plug usual Pump Gov.. Connection
ENGINEER'S BRAKE VAIVE
⅜" Copper Pipe Train Line Pressure
DUPLEX GOVERNOR
Adjusted to 100 or 110 lbs.
Adjusted to 70lbs.
To Boiler
To Pump
⅜" Copper Pipe Main Reservoir Pressure.
1" CUT OUT COCK.
MAIN RESERVOIR.
1" Train Brake Pipe.

FIG. 11.

handle of the brake valve is thrown into the full-release position. This is important, especially after a release of the brakes on a descending grade. When carrying the brake-valve handle in running position the low-pressure governor head regulates the pump, and maintains standard pressures in the train pipe and main reservoir, the excess-pressure valve maintaining 20 pounds excess pressure.

When the brake-valve handle is lapped after a service reduction, the low-pressure governor is cut out of service and the high-pressure governor is cut in. This head stops the pump when main-reservoir pressure reaches the pressure at which the governor is set to operate.

This arrangement can also be used to advantage on freight engines handling very long trains on comparatively level roads. The advantages gained by this method in such service are that the air pump does not have to work against the high main-reservoir pressure except during the short period when the brakes are applied, and that a high main-reservoir pressure is assured at the time it is really needed.

With this arrangement safety valves on the driver brake and tender cylinders are not required as is necessary in connection with the first arrangement described in Art. 22.

THE WATER BRAKE.

PRINCIPLES INVOLVED.

34. If the valve gear of a locomotive is reversed while the locomotive is running forwards with throttle closed, the engine cylinders will be converted into air compressors. As the piston moves either forwards or backwards, a vacuum is created in the cylinder behind it and hot gases from the smokebox are drawn in to fill the vacuum. The gases in the cylinder ahead of the piston are compressed, and offer a resistance that acts to stop the movement of the piston, and thus the speed of the engine is retarded.

With the valve gear in the reverse direction to which the engine is running, therefore, the engine cylinders act as brakes

to retard the speed of the train. If the air drawn into the cylinders were cool and free from cinders, this method of braking would be simple and very efficient for use on engines on long down grades. As it is, however, cinders would be drawn into the cylinders and cause trouble; also, the gases in the smokebox are very hot, and, when drawn in, their temperature is still further increased by compression; hence, serious injury would result to the cylinders, valves, and valve seats, if this method of braking were used without some means of preventing the hot gases and cinders from entering the cylinders.

The **water brake** (sometimes spoken of as the LeChatelier brake) overcomes the objections to this method of braking by introducing wet steam at a low pressure into the cylinders, thereby excluding the hot gases. Unfortunately, the term "water brake" is a misnomer when applied to the LeChatelier method of braking, and is very liable to create the impression that water is used in the cylinders, whereas, in reality, the braking is done by means of low-pressure wet steam. Water in the cylinders has been the cause of too much trouble for any one to voluntarily introduce it there.

CONSTRUCTION OF BRAKE.

35. The water brake was invented nearly fifty years ago by a prominent French engineer named LeChatelier, but it was not introduced in this country until years afterwards, being first used on the early mountain roads in the Rocky Mountains, a region where it has proved a very valuable auxiliary braking device. The water brake is shown applied to an engine in Figs. 12 and 13, the former being a plan view of engine and the latter a view taken at rear of cylinders. The brake apparatus consists of an ordinary globe valve *a* and sufficient piping *b b b* to connect the valve with the exhaust passages in the cylinder saddle at *c*, *c*. The globe valve is set in the boiler head, on a level with the crown sheet and at a point where it will be within easy reach of the engineer. The pipe used in connection with the globe valve is either a $\frac{3}{8}$-inch or a $\frac{1}{2}$-inch pipe, depending on the size of the engine cylinders. It divides into

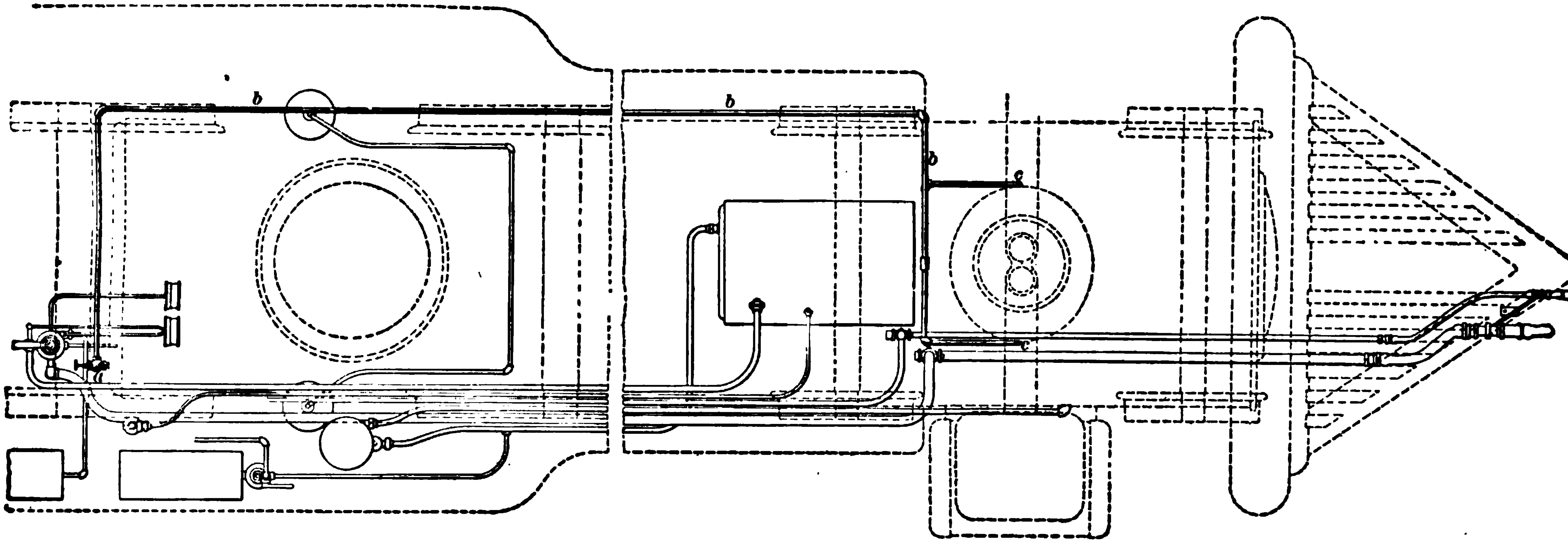

FIG. 12.

two branches at the cylinder saddle, each branch leading to, and opening into, one of the exhaust passages, as shown.

OPERATION OF PARTS.

36. As previously stated, the duty of the water brake is to supply low-pressure steam to the cylinders when the engine is running reversed, so that, by acting as compressors, the cylinders can be used as an auxiliary braking device without being injured by hot gases and cinders from the smokebox. It is well known that water will boil at 212° F., if in the open air; but, if subjected to a boiler pressure of, say, 180 pounds

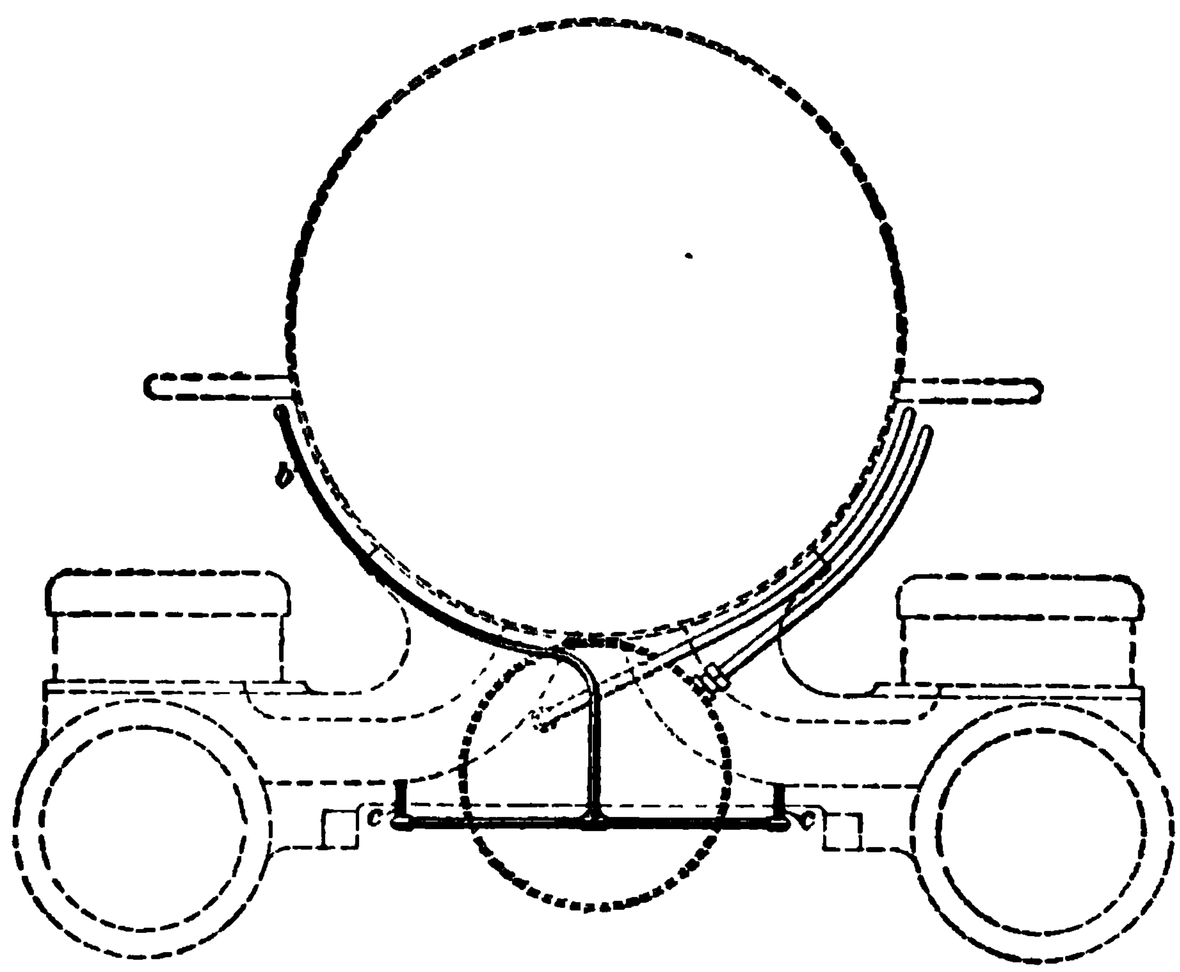

FIG. 13.

gauge, it will not boil until its temperature has been raised to about 380° F. If, now, some of the water in the boiler is allowed to escape into a pipe or vessel connected with the atmosphere, its temperature will be far greater than 212° F.; hence, it will boil and be converted into steam. The temperature of this steam, however, falling considerably during the conversion, the pressure exerted by it will be reduced accordingly.

The valve and piping of the water brake simply provides the engineer with a convenient means of introducing water from the boiler into the exhaust passages in the cylinder saddle,

where it is immediately converted into steam for use in the cylinders. By introducing the water into the exhaust passages, a vacuum is prevented from forming therein; hence, there is no tendency for the hot gases in the smokebox to be drawn into the cylinders.

It thus will be seen that the operation of this brake depends on the excess temperature of the water in the boiler over that required to boil water under atmospheric pressure; if the water in the boiler were at a temperature less than 212° F., it would not be converted into steam when discharged into the exhaust passages, and the result would probably be a broken cylinder head.

OPERATING THE BRAKE.

37. The water brake should always be operated in a certain regular order, which is as follows: First be sure that all the cylinder cocks are open and that the throttle valve is shut; next open the water valve (i. e., the globe valve *a*) about one-quarter turn; then immediately place the reverse lever of the engine one or two notches back of the center and note the color of the steam issuing from the cylinder cocks. If dense white in color, the water valve is open sufficiently, but if the steam has a bluish color at the cylinder cocks, which gradually changes to grayish white as its distance from the cock increases, the water valve should be opened a little wider until the steam has a dense white appearance from the moment it leaves the cylinder cocks. If the engine throws water from the stack, the valve is opened too wide and should be closed sufficiently to stop the trouble.

The amount of braking power exerted by the water brake depends on the position of the reverse lever. When it is in the first notch from the center, it exerts the least braking power, and the braking power is increased as the lever is moved toward the corner notch. The retardation of speed should therefore be regulated by placing the reverse lever in the notch required, and the water valve should not be changed after once being adjusted.

The water brake can be used when the engine is running

either forwards or backwards, by simply placing the reverse lever so as to convert the cylinders into air compressors, observing the same rules of operation, regardless of the direction of running.

When it is desired to shut off the water brake, first close the water valve *a* and then *slowly* move the reverse lever toward the center, to avoid throwing water from the stack.

The water brake, it must be remembered, acts to stop the rotation of the drivers, so that if the driver brake is used in conjunction with it, the braking force acting on the drivers will be too great, and they will be skidded. The water brake is simply an auxiliary braking device and should be used intelligently. It is most effective on a steady motion of from 3 to 12 miles per hour, is less effective at speeds greater than 12 miles per hour, and it should not be used at a greater speed than 18 miles per hour.

In double-heading on a grade, the engineer not operating the air brake assists in retarding the speed of the train by using the water brake to whatever extent advisable.

THE SWEENEY AIR COMPRESSOR.

PRINCIPLES OF WORKING.

38. The **Sweeney air compressor,** or the "Sweeney," as it is commonly called, is an air-compressing device that is used quite extensively on Western roads, where the grades are heavy. It is not intended to replace the ordinary air pump, but rather to act as an auxiliary compressing device to help out the pump. In case the pump becomes disabled, however, it may be made supply the entire amount of air necessary to bring the train safely down the grade.

CONSTRUCTION OF COMPRESSOR.

39. Two views of the Sweeney, applied to an engine, are given in Fig. 14 (*a*) and (*b*). It will be seen that a 1¼-inch pipe is tapped into the top of the steam chest at *a* and thence

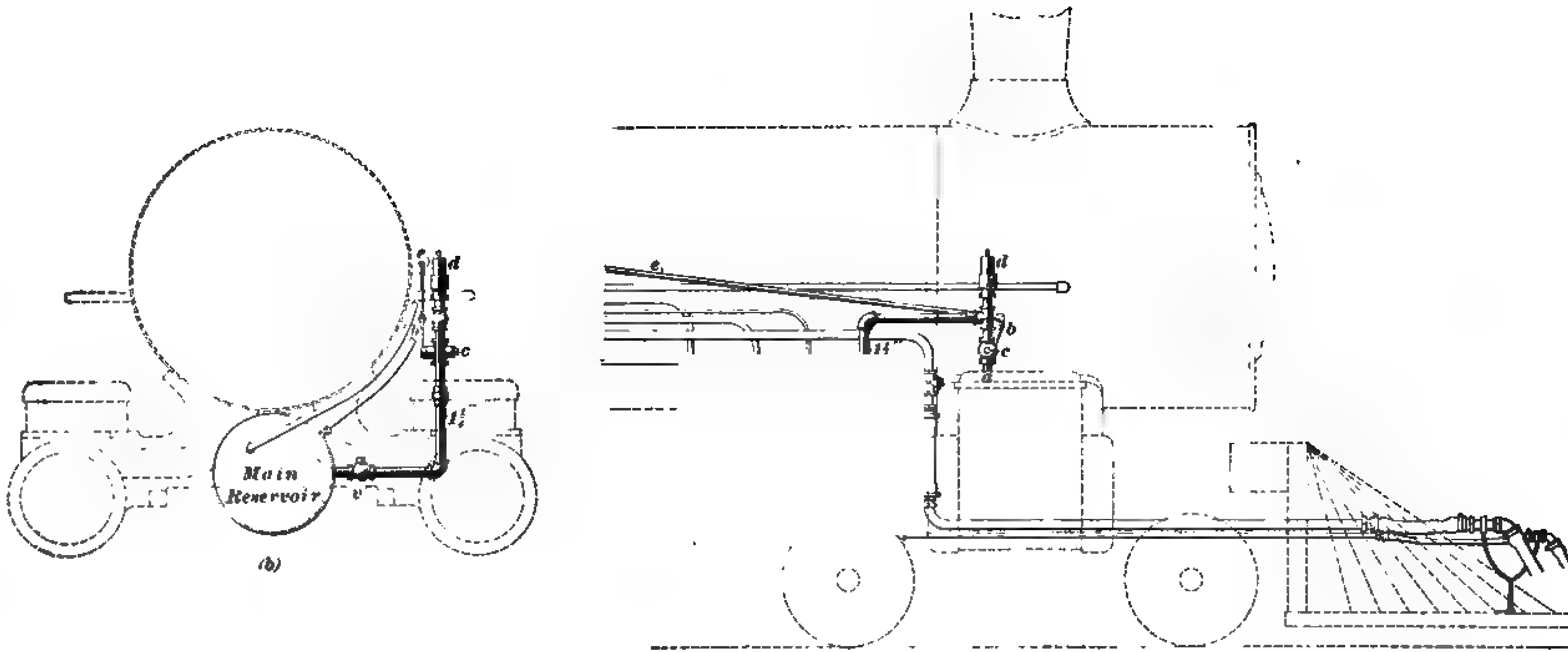

Fig 14

leads to the main reservoir. A stop-cock *c* is placed in the pipe so as to control the passage through it. This stop-cock can be opened and closed from the engine cab by means of the rod *e*, which is connected to the lever *b* of the stop-cock. Pushing the handle forwards opens the cock, while pulling it backwards closes it. Also, a check-valve *v* is placed in the pipe, close to the main reservoir. The object of this valve is to prevent pressure from flowing from the main reservoir back through the pipe to the steam chest. A safety valve *d* is also provided, which prevents the main reservoir from being overcharged, since it will open and allow the air to discharge from the cylinders to the atmosphere when main-reservoir pressure is raised to the pressure for which the safety valve is adjusted.

OPERATING THE COMPRESSOR.

40. To operate the Sweeney, the throttle must, of course, be closed, and the engine running. The cylinder cocks should first be left open while the drivers make two or three revolutions, so as to get rid of any water there may be in the cylinders. The engineer's brake valve should then be placed on lap, the stop-cock *c* opened, and the engine reverse lever placed several inches back of the center notch, assuming the engine to be running forwards. By reversing the valve gear while the engine is running, the cylinders are converted into air compressors, and air is compressed and forced into the steam chest and thence through the 1¼-inch pipe to the main reservoir. As the capacity of the steam cylinders is large compared with that of the air-pump cylinder, the main reservoir is charged in a very short time by this method. The reverse lever must be left back of the center notch at least 15 seconds after the gauge indicates standard pressure.

To throw the Sweeney out of service, place the reverse lever in the forward motion and close the stop-cock *c*; care must always be taken to see that the stop-cock is closed before steam is used, since, if it is left open, the air-brake system will be charged with steam when the engine throttle is opened, and trouble will surely result.

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